# Nordic-Baltic Forest Growth and Yield conference

August 26 - 28, 2025

Tartu, Estonia

EMÜ

METSAHOIU SIHTASUTUS

**Editors: Toomas Tarmu, Andres Kiviste**

**Eesti Maaülikool, 2025**

# Contents

Contents ..... 3
Committees ..... 5
Schedule ..... 6
Maps, Venues ..... 7
Presentations Schedule – day 1 ..... 8
Poster Presentations Schedule I ..... 9
Poster Presentations Schedule II ..... 10
Presentations Schedule – day 2 ..... 11
Abstracts (oral presendations) ..... 12
Environment-induced growth changes in forests of Finland revisited ..... 12
Long term evaluation of a high yield experiment in Norway spruce ..... 13
Approaches used in forest growth and yield model 'AGM' for forest resource assessment under different management regimes in Latvia ..... 14
Modelling the merchantable timber and logging residues amounts in clear felled areas in Lithuania . 15
Growth and yield in scots pine progeny trials: investigating the interaction between genetics and thinning ..... 16
Effects of clearcut age at planting and slash removal 30 years after establishment of Norway spruce 17
Validation of the performance of MOTTI simulator in predicting long-term development of Scots pine and Norway spruce stands in Finland ..... 18
Improved stand structure forecasting for practical forestry using stochastic modelling ..... 19
Growth and competition in mixed forests of oak and rare broad-leaved tree species in southern Scandinavia ..... 20
Effects of naturally emerged broadleaf admixture in conifer dominated stands to profitability and yield ..... 21
Tree growth and field-layer vegetation 17 years after mechanical site preparation and pre-harvest N fertilization ..... 22
Understanding tree resilience to tree water deficit: implications for forest growth ..... 23
Sustainable cultivation of root sucker generated hybrid aspen ..... 24
Thresholds of facilitation and competition in Nelder trials - how climate modulates the effect of density on tree growth ..... 25

abstracts (poster presendations) ..... 26
High-density birch shelterwoods: a comparative analysis of growth, yield, and economic viability in planted Norway spruce forests ..... 26
Planting year impacts the development of spruce and birch mixtures ..... 27
Initial growth of different poplar clones under various conditions ..... 28
Evaluating the performance of mainstream swedish growth models in uneven-aged forestry systems ..... 29
Douglas fir under shelterwood of birch ..... 30
Efficient recycling of wood ash to forest land and characteristics of wood ash transformations and plant availability ..... 31
Forest growth and environmental impact of nutrient recycling trough bio-nutrient fertilization ..... 32
Individual-tree models based on Swedish NFI data can capture signal of tree growth decline for Norway Spruce ..... 33
Leveraging AI and forest growth models for sustainable forestry: a Lithuanian case study ..... 34
Influence of ash and fertilizer treatments on the growth of fast-growing broadleaf trees ..... 35
Effect of various site preparation methods and stand densities on growth and development of Norway spruce stands ..... 36
Long-term evaluation of a regeneration experiment using planting and natural regeneration ..... 37

# Committees

## Scientific committee

A. Kangur, Professor, EMÜ, Estonia

S. Huuskonen, Senior Researcher, Luke, Finland

S. Bianchi, PostDoc, Luke, Finland

E. Holmström, Professor, SLU, Sweden

Z. Libiete, Senior Researcher, Silava, Latvia

K. Maleki, Research Scientist, NIBIO, Norway

H. Korjus, Professor, EMÜ, Estonia

A. Kiviste, Professor, EMÜ, Estonia

## Organizing committee

A. Kiviste, Professor, EMÜ, Estonia

H. Korjus, Professor, EMÜ, Estonia

A. Kangur, Professor, EMÜ, Estonia

G. Kroll, Chair Assistant, EMÜ, Estonia

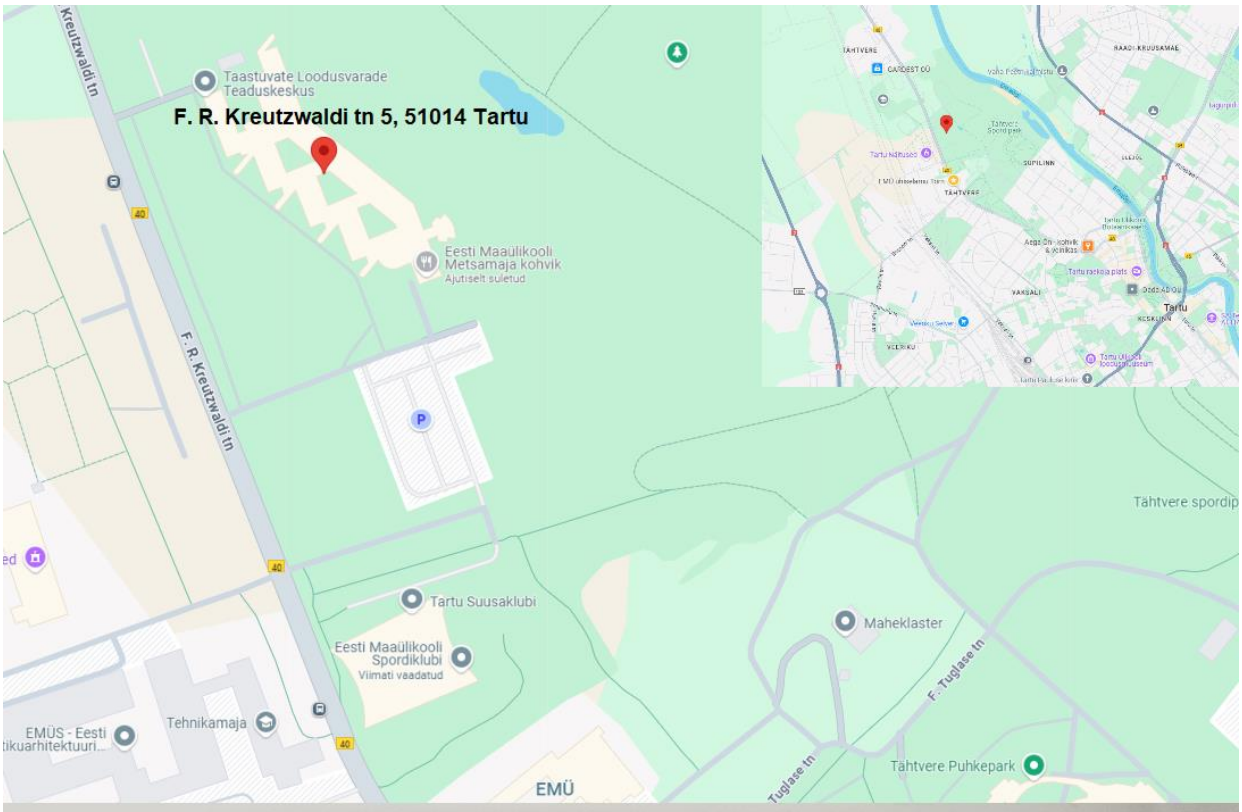
T. Tarmu, Junior Researcher, EMÜ, Estonia

The conference is organized by the Institute of Forestry and Engineering at the Estonian University of Life Sciences (**F. R. Kreutzwaldi 5, 51006 Tartu**).

# Schedule

| Date | Activity | Time |
|---|---|---|
| **26.08** | Arrival (Welcome coffee) | 12:00 – 13:00 |
| | Session 1 (Presentations) | 13:00 – 14:20 |
| | Lunch | 14:20 – 15:20 |
| | Session 2 (Presentations) | 15:20 – 16:40 |
| | Coffee break | 16:40 – 17:00 |
| | Poster session | 17:00 – 18:00 |
| **27.08** | Field trip to North-East Estonia, long-term forest experiments in Aidu quarry | 08:00 – 20:00 |
| **28.08** | Session 3 (Presentations) | 9:00 – 10:20 |
| | Coffee break | 10:20 – 10:50 |
| | Session 4 (Presentations) | 10:50 – 11:50 |
| | Concluding remarks | 11:50 – 12:00 |
| | Lunch | 12:00 – 12:45 |
| | Departure | 12:45 |

# Maps, Venues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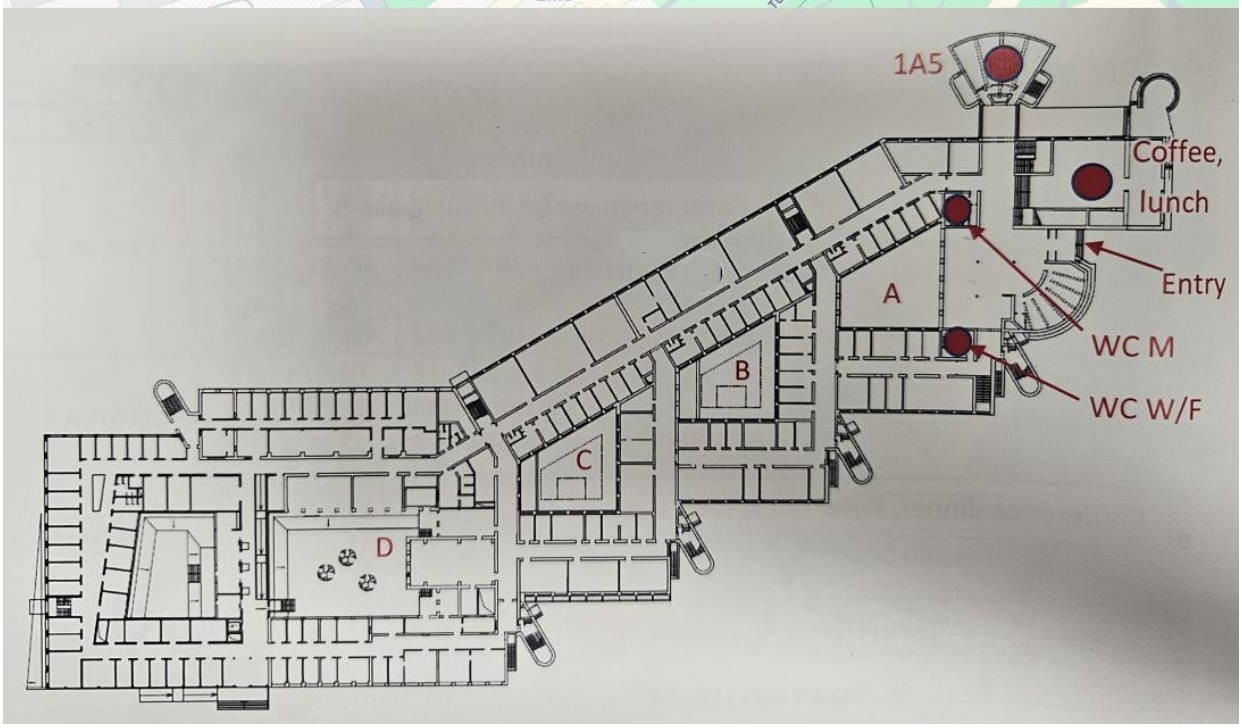
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# Presentations Schedule – day 1

## 26.08.2025

| Time | Schedule |
|---|---|
| 12:00 – 13:00 | **Arrival (Welcome coffee)** |
| 13:00 – 13:05 | **Opening Remarks:**<br>Ahto Kangur, Henn Korjus<br>Estonian University of Life Sciences |
| 13:05 – 13.30 | **Environment-induced growth changes in forests of Finland revisited**<br>Harri Mäkinen<br>Natural Resources Institute Finland |
| 13:30 – 13.55 | **Long term evaluation of a high yield experiment in Norway spruce**<br>Emma Holmström<br>Swedish University of Agricultural Sciences |
| 13:55 – 14:20 | **Approaches used in forest growth and yield model 'AGM' for forest resource assessment under different management regimes in Latvia**<br>Janis Donis<br>LVMI Silava |
| 14:20 - 15:20 | **Lunch** |
| 15:20 - 15:40 | **Modelling the merchantable timber and logging residues amounts in clear felled areas in Lithuania**<br>Edgaras Linkevičius<br>Vytautas Magnus University |
| 15:40 - 16:00 | **Growth and yield in Scots pine progeny trials: investigating the interaction between genetics and thinning**<br>Pauls Zeltins<br>Latvian State Forest Research Institute "Silava" |
| 16:00 - 16:20 | **Effects of clearcut age at planting and slash removal 30 years after establishment of Norway spruce**<br>Axelina Jonsson<br>Swedish University of Agricultural Sciences |
| 16:20 - 16:40 | **Validation of the performance of MOTTI simulator in predicting long-term development of Scots pine and Norway spruce stands in Finland**<br>Daesung Lee<br>Natural Resources Institute Finland (LUKE) |
| 16:40 - 17:00 | **Coffee break** |
| 17:00 - 18:00 | **Poster session** |

## Room: 1A5

# Poster Presentations Schedule I

## 26.08.2025

## Part I

| Time | Schedule |
|---|---|
| 17:00 – 17:05 | **High-Density Birch Shelterwoods: A Comparative Analysis of Growth, Yield, and Economic Viability in planted Norway Spruce forests**<br>Alfred Deutgen<br>Forest research institute of Sweden |
| 17:05 – 17:10 | **Planting year impacts the development of spruce and birch mixtures**<br>Babatunde Dosumu<br>Swedish University of Agricultural Sciences |
| 17:10 – 17:15 | **Initial growth of different poplar clones under various conditions**<br>Michalina Grabowska<br>Southern Swedish Forest Research Centre Alnarp |
| 17:15 – 17:20 | **Evaluating the performance of mainstream Swedish growth models in uneven-aged forestry systems**<br>Mateusz Grzeszkiewicz<br>Swedish University of Agricultural Sciences |
| 17:20 – 17:25 | **Douglas fir under shelterwood of birch**<br>Michal Kibitlewski<br>Swedish University of Agricultural Sciences |
| 17:25 – 17:30 | **Efficient recycling of wood ash to forest land and characteristics of wood ash transformations and plant availability**<br>Linnea Larsson<br>Swedish University of Agricultural Sciences |

## Location: In front of room 1A5

# Poster Presentations Schedule II

## 26.08.2025

## Part II

| Time | Schedule |
|---|---|
| 17:30 – 17:35 | **Forest growth and environmental impact of nutrient recycling trough bio-nutrient fertilization**<br>Johan Lundbäck<br>Swedish University of Agricultural Sciences |
| 17:35 – 17:40 | **Individual-tree models based on Swedish NFI data can capture signal of tree growth decline for Norway Spruce**<br>Maksym Matsala<br>Swedish University of Agricultural Sciences |
| 17:40 – 17:45 | **Leveraging AI and Forest Growth Models for Sustainable Forestry: A Lithuanian Case Study**<br>Arnas Matusevičius<br>Vytautas Magnus University |
| 17:45 – 17:50 | **Influence of ash and fertilizer treatments on the growth of fast-growing broadleaf trees**<br>Iida Puurula<br>Swedish University of Agricultural Sciences |
| 17:50 – 17:55 | **Effect of various site preparation methods and stand densities on growth and development of Norway spruce stands**<br>Edzus Romans<br>Swedish University of Agricultural Sciences |
| 17:55 – 18:00 | **Long-term evaluation of a regeneration experiment using planting and natural regeneration**<br>Therese Strömvall<br>The Swedish University of Agricultural Sciences |

## Location: In front of room 1A5

# Presentations Schedule – day 2

## 28.08.2025

| Time | Schedule |
|---|---|
| 9:00 – 9:20 | **Improved Stand Structure Forecasting for Practical Forestry Using Stochastic Modelling**<br>Martynas Narmontas<br>Vytautas Magnus University Agriculture Academy |
| 9:20 – 9:40 | **Growth and competition in mixed forests of oak and rare broad-leaved tree species in southern Scandinavia**<br>Julia Schmucker<br>Southern Swedish Forest Research Centre, Swedish University of Agricultural Sciences |
| 9:40 – 10:00 | **Effects of naturally emerged broadleaf admixture in conifer dominated stands to profitability and yield**<br>Lauri Männistö<br>Natural Resources Institute Finland |
| 10:00 – 10:20 | **Tree growth and field-layer vegetation 17 years after mechanical site preparation and pre-harvest N fertilization**<br>Edzus Romans<br>Swedish University of Agricultural Sciences |
| 10:20 – 10:50 | **Coffee break** |
| 10:50 – 11:10 | **Understanding tree resilience to tree water deficit: Implications for forest growth**<br>Laura Nikinmaa<br>Natural Resource Institute Finland |
| 11:10 – 11:30 | **Sustainable cultivation of root sucker generated hybrid aspen**<br>Nils Fahlvik<br>Forest research institute of Sweden (Skogforsk) |
| 11:30 – 11:50 | **Thresholds of facilitation and competition in Nelder trials - how climate modulates the effect of density on tree growth**<br>Dominik Ambs<br>Technical University of Munich |
| 11:50 – 12:00 | **Concluding remarks** |
| 12:00 – 12:45 | **Lunch** |
| 12:45 | **Departure** |

## Room: 1A5

# Abstracts

## Oral presentations

## ENVIRONMENT-INDUCED GROWTH CHANGES IN FORESTS OF FINLAND REVISITED

Harri Mäkinen
Natural Resources Institute Finland

After a rising trend from the beginning of 1970s, during which the overall annual growth of the forests of Finland increased by more than 70 %, a recent reduction has been observed. We analyzed the development of annual growth, focusing on the component not explainable by changes in growing stock or forest structure.

The data originate from the Finnish National Forest Inventories. We developed models predicting periodic (5 years) annual volume increments per hectare with properties of the trees and the stands as predictor variables. Deviations from model-predicted values in large areas were interpreted to be induced by environmental variation. The development was analyzed separately for three species groups: Scots pine, Norway spruce and broadleaves.

We observed a rising growth trend not explainable by forest structure. The species groups produced rather a similar pattern in different parts of Finland: from the 1960s to mid-1990s, measured volume increment was mainly below the model-predicted level, thereafter above it. During the current century, the difference between measured and predicted annual volume increment has shown a downward trend for Scots pine. For Norway spruce, the difference of measured and predicted growth has continued to increase in southern Finland but shows little change in the north. For broadleaved species, a recent increase was detected as well, though not as large as for Norway spruce. The geographical pattern of the environment-induced growth component was described in more detail via maps using a 75 km × 75 km grid. The key question is: are we witnessing a turning point of the long increasing growth trend, or are the recent years just a temporary downturn, a part of natural variation.

**Keywords:** Boreal forests, forest growth, forest inventory, global change, time series analysis

**Authors and affiliaton**
Helena M. Henttonen, Pekka Nöjd, Harri Mäkinen: Natural Resources Institute Finland

# LONG TERM EVALUATION OF A HIGH YIELD EXPERIMENT IN NORWAY SPRUCE

Emma Holmström
Swedish University of Agricultural Sciences

A long term experiment was established in Asa experimental forests, southern Sweden, in 1987 in a 24 year old Norway spruce plantation. In the experiment four treatments were randomized and replicated on the site, in treatment plots of 50 ×50 m size. The treatments were fertilization with solid fertilizer, daily irrigation, fertilization in the daily irrigation and control without any added treatments. The experiment was running with irrigation until 2011 and after this only solid annual fertilization and repeated measurements of the trees every fifth year. Findings from the experiment was published 1999 (Bergh et al). I will present the results the long term effects and growth and stand development until the last measurement 2021, including the history of damage (mainly wind or snow) along time. Although this specific experiment is only located on one site in southern Sweden, the findings from here can be relevant in the current discussion about a dryer and warmer climate during the growing seasons.

1. (Bergh, J., et al., The effect of water and nutrient availability on the productivity of Norway spruce in northern and southern Sweden. Forest Ecology and Management, 1999. 119(1-3): p. 51-62.)

**Keywords:** Fertilization, irrigation, Norway spruce, Sweden

**Authors and affiliation**: Emma Holmström, SLU

# APPROACHES USED IN FOREST GROWTH AND YIELD MODEL 'AGM' FOR FOREST RESOURCE ASSESSMENT UNDER DIFFERENT MANAGEMENT REGIMES IN LATVIA

Janis Donis
LVMI Silava

The growth and yield model 'AGM' is developed based on ~ 5000 NFI permanent sample plot data established in 2004-2008 and re-measured every 5 years (re-measured 3 times) as well as data from series of thinning experiments and shelterwood and selection cutting observational studies. It is non-spatial mixed stand (cohort) model. Modelling is performed in 5 years steps. For each cohort is modeled changes in Hdom, Hq, DBH, G and N. Hdom change is based on GADA model of Hossfeld IV growth function, Hdom and Hq is related to number of trees, DBH change is related to initial DBH, competition and age. Basal area (BA) change depends on initial BA, competition, age, site index, thinning type and intensity. Competition is described as relative density or basal area of larger trees. Mortality is modeled as deterministic part based on age and competition and stochastic part based on probabilities of natural disturbances (wind&snow, insects), which depends on species, age, modeled management activities. Model allows to simulate different thinning regimes as well as growth shelterwood and selection management regime. Ingrowth (regeneration) consists of trees from anthropogenic regeneration and natural regeneration. Natural regeneration is stochastic process, which depends on forest type. Volume of stems is calculated based on function elaborated by I. Liepa (1996), while assortment structure is modeled based on stem taper of trees elaborated by R.Ozolins (1986), but diameter distribution is modeled based on Weibull function. Correction for low quality assortments is applied. Biomass of above ground part and below ground part is calculated according to Liepiņš et al. (2018,2021), carbon content according to Bardule at al., (2021).

**Keywords:** Hossfeld IV, GADA approach

**Authors and affiliaton**
Janis Donis, Guntars Šņepsts LSFRI "Silava"

# MODELLING THE MERCHANTABLE TIMBER AND LOGGING RESIDUES AMOUNTS IN CLEAR FELLED AREAS IN LITHUANIA

Edgaras Linkevičius
Vytautas Magnus University

In Lithuania, the merchantable timber amounts were estimated only for chainsaws. However, harvesters have already been logging in final felling for the last decade despite usually producing more cutting residues. In this study, we calculated the yield of merchantable wood for harvesters and compared it with the applicable standards in the forests managed by the State Forest Enterprise (VĮ VMU) and private forest owners. We also calculated the overall yield of merchantable wood and the yield according to forest hydrotropes. We identified the key factors determining the yield of merchantable wood. After analyzing the structure of the tree volume, we modelled its main elements based on tree diameter, both for tree species pine, spruce, birch, aspen, black alder and gr alder. In total, more than 3500 model trees were measured to perform this analysis. We also measured the aspects of tree volume structure and compared the results with tree volume structure tables.

Accordingly, the main elements of forest harvesting residues (such as a stump, bark, logging residues, stem waste, branches, tops, and all residues) were modelled based on tree diameter, for all analyzed species collectively and for each species separately. To assess the differences in the quantities of forest harvesting residues and their elements when cutting with harvesters versus chainsaws, the measured quantities of residues and their elements in this study were compared with the residue models presented by Petrauskas et al. (2009).

Based on the findings, recommendations on merchantable timber amounts were made to Lithuanian politicians.

**Keywords:**

**Authors and affiliaton**
Edgaras Linkevičius

# GROWTH AND YIELD IN SCOTS PINE PROGENY TRIALS: INVESTIGATING THE INTERACTION BETWEEN GENETICS AND THINNING

Pauls Zeltins
Latvian State Forest Research Institute "Silava"

Understanding the interaction between genetic variation and thinning in planted stands is crucial for optimizing both tree breeding and silvicultural practices in long-term. This study examines four progeny trials of Scots pine families, where first commercial thinning was conducted at approximately 30–40 years of age. Within each trial, thinning reduced basal area to two target levels (either 8 and 12 $m^2$ $ha^{-1}$ or 15 and 20 $m^2$ $ha^{-1}$). To maintain the experimental design, half of the replications in each trial were thinned to one basal area, and the other half to the alternative. Measurements of DBH and height (H) were available before thinning, with DBH re-measured five years after thinning. Genetic parameters, including narrow-sense heritability ($h^2$) , were estimated for DBH. Results showed that neither family nor thinning intensity had a significant effect on DBH five years after thinning, with initial DBH being the strongest predictor of post-thinning diameter. However, strong family effects were observed for DBH and H before thinning. Importantly, genotypic diversity (number of families) was not reduced after thinning, suggesting that the best trees from each family were retained. Five years after thinning, yield ranged from approximately 75 to 233 $m^3$ $ha^{-1}$, while tree density varied from 293 to 524 trees $ha^{-1}$ depending on site and thinning intensity. Furthermore, increased $h^2$ estimates for DBH after thinning suggest that thinning may allow genotypes to better express their inherited growth potential. These findings highlight the interaction between tree breeding and commercial thinning and provide insights into their potential long-term effects on forest productivity.

**Keywords**: commercial thinning, genetic variation, tree breeding

**Authors and affiliaton**
Pauls Zeltiņš, Andis Adamovičs, Āris Jansons. Latvian State Forest Research Institute "Silava".

# EFFECTS OF CLEARCUT AGE AT PLANTING AND SLASH REMOVAL 30 YEARS AFTER ESTABLISHMENT OF NORWAY SPRUCE

Axelina Jonsson
Swedish University of Agricultural Sciences

Treatments done in the regeneration phase significantly affect seedling growth and survival. Postponing regeneration up to four years after clearfelling can reduce seedling damage and mortality caused by pine weevils (Hylobius abietis), which is a serious damage agent in conifer regenerations. However, under delayed establishment, competing vegetation can colonize the site, possibly reducing seedling growth. Slash removal after clearfelling can facilitate later regeneration treatments such as site preparation and planting, increasing planted seedlings' survival. But slash removal can also reduce long-term stand growth, due to nutrient removal from the site.

In this study, the long-term effects of clearcut age, i.e. years since the clearfelling was done, and slash removal on volume production was evaluated 30-years after planting Norway spruce. Data for this study was collected from a long-term experiment established between 1989 and 1993. The experiment included four sites in southern Sweden. At each site, a clearcut was made every year from 1989 to 1993. To study the slash-removal effect, slash was retained on half of the clearcut area and removed from the other half. To study the effect of clearcut age, clearcuts were planted each subsequent year until the end of the experiment, creating five different clearcut ages. Clearcut ages were compared when they had reached the same age, thereby not accounting for the growing seasons lost for the oldest clearcut ages compared to the youngest. For the 1500 largest trees per hectare, the total volume significantly differed among clearcut ages. The youngest clearcut age had higher total volume than the oldest. There was also a significant difference between slash treatments, where slash removal lowered total volume compared to slash retention. However, delaying regeneration treatments caused a larger total volume loss than slash removal.

**Keywords**: Forest regeneration, planting, delayed regeneration, long-term effects, *Picea abies*

**Authors and affiliaton**
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[3]Linnaeus University, Faculty of Technology, Department of Forestry and Wood Technology, SE-35195 Växjö, Sweden

# VALIDATION OF THE PERFORMANCE OF MOTTI SIMULATOR IN PREDICTING LONG-TERM DEVELOPMENT OF SCOTS PINE AND NORWAY SPRUCE STANDS IN FINLAND

Daesung Lee
Natural Resources Institute Finland (LUKE)

Predicting forest growth and yield accurately and precisely is crucial for addressing forest management issues related to societal, environmental, and economic concerns. In Nordic production forests, controlling stand density and rotation length are the most common management practices applied. There is also long-term growth and yield research using empirical data to address the effects of these practices in the form of models and prediction systems. To provide reliable support for forest planning, model-based planning tools and stand simulators must be evaluated using available long-term empirical data. We evaluated the decision-support system for forest management in Finland, known as MOTTI, by comparing model predictions with measurement results using data from Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*) experiments located in southern and central Finland. The total number of plots was 43 for Scots pine and 30 for Norway spruce. The experiments were measured repeatedly, mostly every 5–7 years, over an average observation period of 32 years. We assessed the performance of the MOTTI simulator using input information available in practical forest datasets, focusing on the reliability of its simulation results for key stand variables in forest planning. We used measured stand variables from experimental plots as input and evaluated the model's accuracy in predicting the development of critical stand attributes: stand basal area and volume, basal area weighted mean diameter and height, and stand dominant height. In the evaluation, we focused on the unbiasedness of the predicted development of stand characteristics with respect to thinning intensity and stand age. Preliminary results indicated no serious trends in model bias with respect to thinning intensity or stand age. We consider this validation helpful for assessing the validity of MOTTI in supporting decision-making and for guiding future model development work.

**Keywords**: *Pinus sylvestris*; *Picea abies*; MOTTI simulator; model validation; Forest decision-support system

**Authors and affiliaton**
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# IMPROVED STAND STRUCTURE FORECASTING FOR PRACTICAL FORESTRY USING STOCHASTIC MODELLING

Martynas Narmontas
Vytautas Magnus University Agriculture Academy

Reliable growth and yield projections are essential for operational forest management, yet standard modelling approaches often fail to capture the structural complexity and irregularities observed in natural stands. This study introduces a stochastic differential equation (SDE) modelling framework, applied to Scots pine (*Pinus sylvestris* L.) and Mountain pine (*Pinus mugo* Turra) forests, with the aim to improve the accuracy and realism of growth forecasting.

The models developed in this study incorporate both fixed and random effects, allowing dynamic representation of stem taper, stand basal area, and volume over time. By using probability density functions, the models reflect real forest variability and non-linear growth trajectories. These features make the approach suitable for forests with atypical stem forms, particularly those growing under suboptimal or disturbed site conditions.

Validation against independent data sets demonstrated that SDE-based models outperform classical regression models in terms of accuracy and robustness, especially in estimating stand parameters at later growth stages. The ability to quantify uncertainty and simulate stand structure development makes this modelling approach valuable not only for researchers but also for forest practitioners.

The method is scalable, species-independent, and can support yield estimation, thinning scheduling, and timber valuation. It offers a practical decision-support tool in situations where traditional models underperform due to ecological variability or structural irregularities.

# GROWTH AND COMPETITION IN MIXED FORESTS OF OAK AND RARE BROAD-LEAVED TREE SPECIES IN SOUTHERN SCANDINAVIA

Julia Schmucker
Southern Swedish Forest Research Centre, Swedish University of Agricultural Sciences

Current forest management practices in Sweden focus primarily on even-aged stands of conifers managed under the clearcutting system. However, climate change, changing social demands and the increasing importance of biodiversity and conservation aspects pose new challenges on forest management, emphasizing a need for modifications. Key strategies to increase climate resilience and enhance biodiversity while maintaining forest productivity are tree species diversification, the establishment of mixed forest stands and promotion of broad-leaved tree species. Here, especially oak (*Quercus petraea* and *Quercus robur*) mixed with drought-tolerant rare broad-leaved tree species may be a suitable option in fulfilling these 'new' strategies and forest functions.

This study presents initial results from a long-term experiment established during 2012-2014 in Sweden and Denmark, investigating the growth, yield, mortality, and competitive interactions in mixed stands of oak with hornbeam (*Carpinus betulus*), hazel (*Corylus avellana*), wild service tree (*Sorbus torminalis*), and field maple (*Acer campestre*). We examine diameter and height growth of these species under different competition settings and site conditions. The aim of the study is to get more information on the production potential of mixed oak forests in southern Scandinavia and to provide information on the management of that forest type.

**Keywords:** oak, rare broad-leaves, growth, competition, Scandinavia

**Authors and affiliaton**
Julia Schmucker, Jens Peter Skovsgaard, Southern Swedish Forest Research Centre, Swedish University of Agricultural Sciences

# EFFECTS OF NATURALLY EMERGED BROADLEAF ADMIXTURE IN CONIFER DOMINATED STANDS TO PROFITABILITY AND YIELD

Lauri Männistö
Natural Resources Institute Finland

Mixed forests have been suggested to be a viable alternative to single species monocultures, as they provide wider range of ecosystem services and greater resistance and resilience against disturbances. Aspects that are vital under changing climate, where extreme weather events and pest outbreaks are expected to become more common. However, monocultures have been justified by their ability to produce valuable timber and are often seen as superior in economic profitability. Mainly as the value of conifer timber tend to be higher compared to hardwoods. Aim of this study was to investigate whether admixture financially less feasible alternative and if so, how great the loss of income is. To examine the difference in yield and profitability number of simulations was conducted using Motti simulator, where two management regimes were examined. One where elevated number of naturally emerged broadleaved trees were maintained trough out the rotation period and one following the current business as usual approach. Same stand level simulations were calculated separately for sites with different fertility classes in different parts of Finland. The elevated risk of disturbances for higher proportion of conifers were not considered. Profitability was examined with cumulative cash flow and net present value with 3 % interest rate. Long term average timber prices and costs of silviculture was used.

**Keywords:** Mixed forest, profitability, simulation

**Authors and affiliaton**
Lauri Männistö, Natural Resources Institute Finland

# TREE GROWTH AND FIELD-LAYER VEGETATION 17 YEARS AFTER MECHANICAL SITE PREPARATION AND PRE-HARVEST N FERTILIZATION

Edzus Romans
Swedish University of Agricultural Sciences

Silvicultural practices like site preparation and nitrogen (N) fertilization are more or less commonly applied to increase growth of a stand. These practices could affect the forest ecosystem for several decades, not only the trees, but also the stand structure and field-layer vegetation. Long-term field experiments are thus necessary to study these effects. In this study, two field experiments, Hagfors and Nissafors, established around 1980, were used to study residual effects of previous N-fertilization and disc trenching (DT) on tree growth and field-layer vegetation 17 years after final felling. At both sites, DT reduced tree mortality and increased individual tree growth, resulting in higher stem numbers and tree volume per hectare after 17 years. Previous N-fertilization had no significant effect on tree growth. The field-layer vegetation was affected by DT at both sites. At Hagfors, the most pronounced effects were a reduction in the cover of Cladonia rangiferina, and an increase in Calluna vulgaris after DT. Cladonia rangiferina was also negatively affected by previous N-fertilization. At Nissafors, DT caused a shift in cover of Vaccinium vitis-idaea to Vaccinium myrtillus. The impact of DT on the field layer composition appears to have been caused by the soil disturbance but also the increased shading resulting from the increased tree growth and survival. This study indicates that previous N fertilization and DT affect the field-layer vegetation in the longer term. This should be considered when developing guidelines and forestry practices.

**Keywords:** Nitrogen, disc trenching, ground vegetation, *Pinus sylvestris,* Scots pine, volume growth

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# UNDERSTANDING TREE RESILIENCE TO TREE WATER DEFICIT: IMPLICATIONS FOR FOREST GROWTH

Laura Nikinmaa
Natural Resource Institute Finland

Droughts are increasingly impacting forest yield in Europe by reducing tree growth and exacerbating secondary disturbances like bark beetle infestations. Even mild water-related stresses can inhibit tree growth. Tree water deficit (TWD), the shrinking of stems due to dehydration, is a critical factor in this process as very little growth can occur during a TWD period. This study investigates how the length of TWD periods can be explained over short time scales (days to weeks) and the influence of reoccurring TWD periods on tree resilience during the growing season. We analyzed high-resolution (15-60 min intervals) dendrometer measurements over Europe, combined with climate data. Using individual tree-based analyses and Poisson generalized linear mixed-effects models, we examined how the length of TWD periods is related to their recurrence, minimum TWD, maximum temperature, monthly Standardized Precipitation Evaporation Index (SPEI), and wood anatomy type.

Our findings reveal that more severe stem shrinkage, indicated by higher TWD, together with higher temperature and lower SPEI, prolongs the length of TWD periods. Wood anatomy also plays a significant role, with coniferous and ring-porous species having a lower resilience to recurring TWD periods than diffuse-porous species. Our results prove that the wood type influences tree responses to TWD periods and implicate the need to consider the tree species characteristics in forest management strategies aimed at reducing tree stress for sustained forest growth.

**Keywords:** tree water deficit; dendrometer, tree resilience, wood anatomy

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# SUSTAINABLE CULTIVATION OF ROOT SUCKER GENERATED HYBRID ASPEN

Nils Fahlvik
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Hybrid aspen is an interesting alternative in developing renewable raw materials and as an energy source. We have some knowledge about the first generation of planted hybrid aspen. This generation can achieve a mean annual stem volume production of over 20 $m^3$ (approx. 7 Mg of dry matter) per hectare on fertile land in southern Sweden. The next generation is characterized by very dense root sucker regenerations. There is a great need for basic research on management concepts for the following generations of root suckers. One alternative is to take advantage of the high biomass production in these regenerations through harvesting biomass. This can either be done in concepts entirely focused on biomass harvesting at frequent intervals. It can also be done in a concept where biomass is harvested in the young stand and where 1200 stems per hectare are left to then be managed according to the conventional model. To test the sustainability of frequent biomass removals, an experiment was established after clear felling of a planted hybrid aspen stands on former arable land in southern Sweden. Three alternative management concepts of root suckers were tested, including rotations of 4, 8 and 16 years. The experiment has now been followed for 16 years, which means that four, two and one full rotations has been completed within the three treatments, respectively. Initial measurements showed root shoot regenerations of over 100,000 stems per hectare. After a few years, a production of 10 Mg of dry matter woody biomass per year and hectare was achieved. The number of stems in the fourth generation of four-year rotations was lower than in the first. Now, after all treatments have completed at least one rotation, conclusions on the sustainability of production will be presented.

# THRESHOLDS OF FACILITATION AND COMPETITION IN NELDER TRIALS - HOW CLIMATE MODULATES THE EFFECT OF DENSITY ON TREE GROWTH

Dominik Ambs
Technical University of Munich

Neighbourhood density is a key driver of tree growth, and optimizing this relationship has been the subject of extensive research. Yet, the effects of intense summer droughts, alongside anticipated environmental shifts associated with global change, highlight the need to revisit the density-growth relationship. Previous studies suggest that reducing density can mitigate drought impacts on growth, while others have demonstrated that increased neighbourhood density may also have positive effects on tree growth.

In this study, we investigate the interactions between stand density, climatic site conditions and temporal climate variability in their impact on tree growth and productivity. To explore those relationships, we relied on a unique data set derived from repeated measurements of five experimental Nelder trials, each with 504 pedunculate oak (*Q. robur*) trees, and established along a climatic gradient in Central Europe 11-17 years ago. For the statistical analysis we relied on non-linear (GAM) and linear (LMM) to assess the relationship between neighbourhood density and tree growth.

We found that density can positively influence tree growth, though this effect is highly context dependent. Preliminary results suggest that young trees growing in intraspecific neighbourhoods exhibit higher stem biomass increments compared to solitary trees. This facilitation effect shifts with increasing age to lower densities (age 17: < 500 N $ha^{-1}$) but is only weakly enhanced by site aridity. Including temporal climatic variability (SPEI) into our models reveals a strong negative influence on tree growth on sites with a negative water balance, while the interaction of drought and density is relatively stronger on more humid sites.

Finding out new optimum stem density levels which incorporate drought reactions can support decision making in forest management, but also improve our understanding of tree-to-tree interactions along tree ontogeny and under various density, site and climatic conditions.

**Keywords:** Tree growth, density, neighbourhood effects, density-drought interaction

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# Abstracts

## Poster presentations

## HIGH-DENSITY BIRCH SHELTERWOODS: A COMPARATIVE ANALYSIS OF GROWTH, YIELD, AND ECONOMIC VIABILITY IN PLANTED NORWAY SPRUCE FORESTS

Alfred Deutgen
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Norway spruce is one of the two most commonly planted tree species in Sweden, while birch species (*Betula pendula* and *Betula pubescens*) are most often naturally regenerated. Traditional forest management involves removing birch during pre-commercial thinning, but mixtures of birch and Norway spruce offer potential benefits. These mixtures may providing frost protection for Norway spruces and reduce the number of stump sprouts from birch while also creating economic value from birch. Previous research have shown that birch initially tends to grow faster than Norway spruce, resulting in higher total volume yields in mixed stands compared to spruce monocultures, although spruce growth can be lower under birch canopies.

This study analyzed seven sites in southern Sweden with dense birch shelters over spruce to promote an early, profitable removal of birch. Monocultures of spruce was used as control group. With annual measurements from 2017 to 2024, the experiment provides a unique possibility to follow the growth dynamics in this concept together with an analysis of how this effects profitability in the stand.

Spruce growth under the birch shelterwood showed significant reductions in both height and diameter. Basal area increment models were constructed to investigate the effect of shelter on individual tree growth in spruce. One model examined how the presence of a birch shelterwood affected spruce growth compared to spruce without shelter. The second model included the distance between spruce and birch.

**Keywords:** Basal area growth, Mixed effect model, NPV

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# PLANTING YEAR IMPACTS THE DEVELOPMENT OF SPRUCE AND BIRCH MIXTURES

Babatunde Dosumu
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Enrichment/replacement planting in regenerations can sometimes be necessary. As extreme years of drought, flooding etc during the planting season might be even more common in the future, exposing forest managers to unexpected risks. The question is then, how will forest stands develop if the replacement planting also creates mixed forests. This study provides knowledge on the effect of enrichment/replacement planting with other species in the case of a low seedling survival after the first year of stand establishment. Spruce (*Picea abies*) and birch (*Betula* spp.) mixtures are common and well-studied in Fennoscandia. Nonetheless, it is rarely a deliberate management choice, typically it occurs from spontaneous natural regeneration of birch during the establishment of planted spruce monocultures. This study however, investigates the development of well-designed planted birch and spruce mixed species experiment established in southern Sweden. The experiments included birch (1) and spruce (2) monoculture, birch planted one year before (3) or after (4) spruce and both species planted in the same year (5). Offering an opportunity to discuss the effect of species composition and initial stand structure on development of mixed stands. Based on the results from measurements 31 and 36 years after stand establishment: Basal area weighted mean diameter and height of spruce was significantly lower in the mixed stands, where it was planted in the same or one year after birch. However, basal area weighted mean diameter and height of birch were similar across the monoculture and mixed stands. Although there was an early fast growth of birch, at mid-rotation, spruce is now growing faster in both the monoculture and mixed stands. Thus, regeneration timing, birch admixture and initial stand structure affect the growth of spruce in mixtures early in the rotation.

**Keywords:** competition, growth, spruce, birch

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# INITIAL GROWTH OF DIFFERENT POPLAR CLONES UNDER VARIOUS CONDITIONS

Michalina Grabowska
Southern Swedish Forest Research Centre Alnarp

Nowadays, in the face of increasing demand for woody biomass, there is a need for improvement in the productivity of forests. It seems reasonable to seek alternatives to the most common tree species in Swedish forestry, such as Scots pine or Norway spruce. Thus, Populus species and their hybrids tend to be the most promising option thanks to their large growth potential at a very short rotation, achieving in optimal conditions the volume up to 30 $m^3*ha^{-1}*yr^{-1}$ under a rotation of 20 years.

Several studies on various poplar clones show a large diversity in growth rate between clones. Through proper selection of poplar clones, biomass production can be maximized.

Currently the most commonly used clone for poplar plantations in the southern part of Sweden is clone OP42.In my studies I am testing 78 different clones belonging to 9 different families that have been selected from crosses between *Populus maximowiczii* and *P. trichocarpa*, which are also parental species for clone OP42. Those crosses were performed in Quebec, Canada. I am assessing the initial growth of those clones under different conditions: with vegetation control and without vegetation control and compare it to the reference clone – OP42.

After two growing seasons trees in the treatment with vegetation control grew to more than double the height of those without vegetation control, with an increase of about 135%. That tells how important the initial growth conditions are. 90% of tested clones grown with vegetation control and 75% without vegetation control obtained greater heights than clone OP42.

The initial results are promising and may lead to finding supplementary clones to OP42 which ensure higher biomass production as well as genetic diversification.

**Keywords:** poplars, fast-growing broadleaves, biomass, growth

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# EVALUATING THE PERFORMANCE OF MAINSTREAM SWEDISH GROWTH MODELS IN UNEVEN-AGED FORESTRY SYSTEMS

Mateusz Grzeszkiewicz
Swedish University of Agricultural Sciences

Continuous Cover Forestry (CCF) practices are increasingly recognized for their potential in climate change adaptation and biodiversity conservation. Selection cutting, a key method within CCF, presents unique challenges for forest growth modelling due to its complex structure and distinct growth dynamics. Current models, largely developed from data obtained from even-aged stands, may exhibit lower accuracy when applied to uneven-aged stands. This study assessed the short-term (i.e., up to 15 years) predictive accuracy of the Swedish Heureka Decision Support System for stands managed with selection cutting. It assessed growth models for tree recruitment, growth, and mortality using data from 27 CCF field experiments covering a broad latitudinal and environmental range across Sweden. A linear mixed-effects modelling approach was used to analyse differences between observations and model predictions. Findings revealed potential species-specific biases, with an average underestimation of volume growth by 2 $m^3\ ha^{-1}\ yr^{-1}$ after ten years of simulation, driven predominantly by underestimations in Norway spruce growth. While mortality predictions were generally accurate, they exhibited slight underestimation after recent cutting and overestimation otherwise. Ingrowth density predictions demonstrated minor biases, with spruce being underestimated and birch overestimated, but displayed high residual variability. Sensitivity analysis revealed correlations of residuals with stand variables, including site index, proportion of spruce, and stand basal area. The study faced limitations due to data scarcity and the short observation periods. Although most observed biases were not statistically significant, the findings underscore potential discrepancies when applying current Swedish models to selection cutting stands.

**Keywords:** Boreal forestry, continuous cover forestry, growth models, Heureka system, model assessment, uneven-aged forest

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# DOUGLAS FIR UNDER SHELTERWOOD OF BIRCH

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Swedish University of Agricultural Sciences

Douglas fir (*Pseudotsuga menziesii*) is an introduced tree species in Europe with high productivity potential when grown under suitable conditions. In Sweden, it is classified as an alien species and is planted on a limited scale in the south. However, its establishment is often challenged by frost damage. To mitigate this risk, protective shelter from other tree species, such as naturally regenerated birch, can be used to moderate temperature fluctuations by reducing direct sunlight and heat radiation loss at night.

This study examines the growth performance of Douglas fir under different levels of birch shelter at Asa Experimental Park in Småland. Experimental plots were established in 2014 with five treatments, each replicated four times:

1. Open areas without a screen
2. 1500 birches per hectare
3. 1500 spruces per hectare
4. 1500 birches mixed with spruce per hectare
5. 3000 birches per hectare

Data on frost damage, peak shoot length, total height, side shoot formation, vegetation cover, and survival were collected from a total of 320 Douglas fir seedlings between 2014 and 2018. However, frost damage and vegetation cover were only measured in 2015.

Results indicate that low-density birch shelter had a positive effect on Douglas fir growth. Seedlings grown under birch cover experienced less frost damage, fewer double shoots, and better overall development. In contrast, seedlings in open areas exhibited less favorable growth conditions. Variability in height and shoot growth was observed across treatments, with the control plot generally providing the least protection against frost and growth disturbances.

These findings suggest that the use of a birch shelter can improve the early establishment of Douglas fir in Sweden, supporting better growth conditions and maximizing its productive potential.

**Keywords:** douglas-fir, shelterwood, frost, growth, silviculture

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# EFFICIENT RECYCLING OF WOOD ASH TO FOREST LAND AND CHARACTERISTICS OF WOOD ASH TRANSFORMATIONS AND PLANT AVAILABILITY

Linnea Larsson
Swedish University of Agricultural Sciences

My PhD project aims to study the direct and indirect impacts on the environment of the return of wood ash, which originates from forest residues, back to forest. Wood ash is today returned to forest land to some extent in southern Sweden, and can contribute to maintaining the soil productivity in whole-tree harvested forests and to increase tree growth on certain sites. The project will study alternative spreading methods for wood ash, where we will return wood ash to forest land in piles of different sizes, and compare to even distribution. The aim is to simplify and streamline the return of wood ash with the possibility of using empty return transports in forest harvest operations. The effects on the environment from adding wood ash in piles on forest land will be investigated in a field trial in conifer forest on mineral soil, where the leakage of added elements into soil, groundwater, and the uptake in trees and vegetation will be monitored. Except for element concentrations, phases of the added elements will be identified to investigate the plant availability. In the field trial, we will include both different temporal scales and spatial scales, with samplings on different periods of the field season, over several years and at different distances from the ash. The field study will be carried out on three sites in southern Sweden, at Asa experimental forest and three sites in northern Sweden, at Vindeln experimental forest. How wood ash in piles affects the surrounding environment, and the contribution to the understanding of alternative spreading methods, will increase the knowledge of wood ash as an amendment in forests. The project will contribute to the knowledge of sustainable and bio-based value chains with wood ash as a resource, and to improve the utilization of bio-based materials.

**Keywords:** wood ash, conifer forest, forest fertilization, biogeochemistry, solubility

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# FOREST GROWTH AND ENVIRONMENTAL IMPACT OF NUTRIENT RECYCLING TROUGH BIO-NUTRIENT FERTILIZATION

Johan Lundbäck
Swedish University of Agricultural Sciences

This study examines potential long-term growth effects and environmental consequences of applying residues from biogas production (Bio-nutrient) as fertilizer in boreal forests. Bio-nutrient is dried, heated, and hygenised (class A level, Swedish EPA) organic sewage sludge digestate, which is pelletized or granulated. It has a dry matter content >90 %, nitrogen content >3 %, and the same limits for levels of heavy metals and synthetic organic substances as for usage on agricultural land.

The field trials in this study are located in northern Sweden, in eastern part of Norrbotten. The study consists of 22 stands with a total area of 863 ha, that span 19 -78 years old, mostly dominated by pine (*Pinus sylvestris*) and spruce (*Picea abies*), but a mixture of birch (*Betula spp*.) in some cases. Fertilization experiments were conducted over several years between 2006 and 2010. The experimental design includes largescale fertilization with Bio-nutrient, mineral fertilizer (Skog CAN) and control areas. Bio-nutrient used in these field trials had a nitrogen content between 4.1 -4.2 %. The total amount of nitrogen dispersed using Skog CAN where 300kg/ha and for bio-nutrient varied between 348-694kg N/ha between the different stands. Measurements include tree stem growth, nutrient analysis in needles, chemical composition of humus layer and groundwater.

Five years post fertilization, we found that diameter growth increased, increasing volume growth from about four to six m³sk/ha/year, following both bio-nutrient and Skog-CAN fertilization, compared to unfertilized plots. Furthermore, needle nutrient analysis showed enhanced nitrogen and phosphorus uptake in fertilized plots. Groundwater showed no significant increase in heavy metal concentrations and soil chemistry analyses indicated minimal changes in pH and organic matter content following fertilization. Future research will assess the long-term effects 15-20 years after fertilization.

**Keywords:** Fertilization, nutrient recycling, longterm field trail

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# INDIVIDUAL-TREE MODELS BASED ON SWEDISH NFI DATA CAN CAPTURE SIGNAL OF TREE GROWTH DECLINE FOR NORWAY SPRUCE

Maksym Matsala
Swedish University of Agricultural Sciences

National Forest Inventory (NFI) data collected over long time can guide researchers and decision makers on changes in growth trends. Recent studies and technical reports in Sweden based on national NFI measurements delivered new findings on seemingly declining tree growth for Norway spruce and Scots pine in the last decade. These must be validated with aim to understand if global drivers such as climate change could contribute and how forest management should be adjusted.

We used NFI data on permanent plots with trees measured in 1983-2022 and calibrated tree-level models for five-year basal area growth of Norway spruce and Scots pine. Our set of predictors was limited to tree and plot basal area, site index, stand age, plot-level basal area of larger trees, and binary indicator of thinnings in last five years. We fitted log-linear (with bias correction) and exponential non-linear equations. Independent validation data included 10% subset of NFI data for Norway spruce and set of experimental plots for Scots pine. Then, we analyzed temporal patterns of residuals for main ecoregions in Sweden.

We achieved moderate accuracies on validation data at tree level (R2 = 0.6 for Scots pine and 0.49 for Norway spruce, best models) and stand (R2 = 0.56 for Scots pine and 0.81 for Norway spruce, best models) levels. Overall, nonlinear models had less bias. We used them to fit temporal patterns of residuals and did not reveal any change in pattern for period 2010-2017 compared to previous time since 1983, with one exception. The latter is a clear increase in overestimating the growth of Norway spruce in Southern and Middle Sweden by our model. We suggest that further analysis should be conducted to connect this pattern with a possible decline of spruce trees' growth.

**Keywords:** individual tree growth model; Scots pine; growth decline; residual analysis

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# LEVERAGING AI AND FOREST GROWTH MODELS FOR SUSTAINABLE FORESTRY: A LITHUANIAN CASE STUDY

Arnas Matusevičius
Vytautas Magnus University

Forest management in Lithuania is focused on sustainable development, balancing economic, environmental, and social objectives. Covering approximately one-third of the country's land area, forests are a vital resource for biodiversity, timber production, carbon sequestration, and recreation. Understanding forest growth processes and the factors influencing them, requires analyzing relationships between various forest structure variables at tree, stand, and landscape levels.

Artificial intelligence enhances forest planning by processing large datasets, improving decision-making, and promoting sustainability. AI and machine learning methods are widely applied in forestry, allowing the analysis of diverse data sources such as climate conditions, soil properties, and historical forest management records to optimize operations. For instance, AI algorithms can predict tree growth and yield, while ML models assess the impact of forest management practices on biodiversity and ecosystem resilience.

This research aims to develop forest growth functions for Lithuania's forests and adapt the GAYA system, incorporating the country’s unique ecological conditions. These growth functions are being integrated into the GAYA framework to improve the accuracy of forest ecosystem projections in Lithuania. A literature review revealed several AI-based approaches for enhancing forest planning, such as integrating multi-source data and predicting long-term ecosystem dynamics. Preliminary results indicate that reliable tree volume growth estimates depend on various dendrometric parameters, including height, age, diameter, and data on logging activities. The application of ML models enables forest planners to integrate diverse datasets and assess multiple management scenarios more effectively, ultimately improving forest planning processes.

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**Keywords:** Machine Learning, Tree growth prediction

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# INFLUENCE OF ASH AND FERTILIZER TREATMENTS ON THE GROWTH OF FAST-GROWING BROADLEAF TREES

Iida Puurula
Swedish University of Agricultural Sciences

Poplars are fast-growing tree species with rotation times of approximately 20 years, and have potential on producing large amounts of biomass for different industries. For Nordic and Baltic region the mean annual increment of poplars has been reported to be 20-30 $m^3$ $ha^{-1}$ $year^{-1}$. Poplar plantations are currently often located on former agricultural land, but land with sub-optimal soil pH i.e. forest land holds a large potential. Boreal forests have acidic soils with pH from 3.7 to 6.4, and it has been observed that optimal pH value for growth of *P. trichocarpa* is between 5.5 and 6.5, and low pH has been observed to cause mortality and poor growth.

Ash has a high pH value, and therefore it can be used to increase soil pH. Ash has been reported to have abundance of Ca, K, Mg and P, but these are largely un-available to the plants. However, depending of fuel composition in the combustion process P and K can form water soluble complexes that might be available to the plants. In this study, poplar (clone "OP42", *Populus maximowiczii* Henry × *P. trichocarpa* Torr. & Gray) and birch (*Betula pendula* Roth) were grown in three different soil types containing multiple different fertilization/ash mixtures (including ash with water soluble P and K). The experiment was performed in controlled greenhouse conditions. Height, diameter, above and below ground biomass were analysed to identify the most effective treatment for increasing growth of poplar and birch, and to identify how the treatments affect the growth and nutrient uptake. The utilization of ash could enable wider use of poplars in practice, since the low pH of forest soils in Sweden can be limiting for the successful establishment and growth of poplars. In addition, the nutrients available in ash could have a beneficial effect on tree growth.

**Keywords:** Fast-growing broadleaves, ash, fertilization, growth

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# EFFECT OF VARIOUS SITE PREPARATION METHODS AND STAND DENSITIES ON GROWTH AND DEVELOPMENT OF NORWAY SPRUCE STANDS

Edzus Romans
Swedish University of Agricultural Sciences

Mechanical site preparation (MSP) is essential part of forest regeneration and management cycle. This treatment ensures better survival and growth against number of potentially life-threatening and growth hindering factors. Among these factors – suppression by vegetation, pine weevil damage, weather effects (drought, frost, water). MSP has been effective treatment to combat these factors, even extreme weather if the planting has been done correctly. Most common methods in Scandinavia and Baltics for preparing site has been disc trenching and mounding, both delivering successful results. However, these treatments leave significant soil disturbance. Changing soil profile, terrain and vegetation cover. This study compares conventional disc trenching treatment with low intensity disc trenching and soil inversion. In addition, soil treatments were accompanied by various planting densities of Norway spruce. These alternative treatments, could potentially be used on suitable sites as a lower environmental impact treatments. Soil inversion treatment creates mineral soil planting spot, it is done in separate spots, unlike disc trenching that creates continuous rows, and is not extremely elevated such as mounding treatments. Study is replicated in two locations, giving the opportunity to compare tree growth response 7 growing seasons after planting. Initial results from study sites show little differences in height, top shoot height and diameter. Suggesting, that trees grow similarly well in all of the treatments. Conventional disc trenching with typical density of 2500 $ha^{-1}$ had the highest survival rate. However, one of the sites was planted in 2018 when particularly harsh drought event occurred. There is extreme difference of natural regeneration between two study sites, that is likely due to specific location and available seed sources in that area. Achieving great planted tree growth and high amount of natural regeneration could create optimal conditions for high value mixed forests.

**Keywords:** Norway Spruce, mechanical site preparation, stand density, early growth

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TBD

# LONG-TERM EVALUATION OF A REGENERATION EXPERIMENT USING PLANTING AND NATURAL REGENERATION

Therese Strömvall
The Swedish University of Agricultural Sciences

In this study, we revisited an old regeneration experiment in Sweden where the aim was to combine natural regeneration of Scots pine (*Pinus sylvestris*) with planting of Norway spruce (*Picea abies*). We wanted to investigate how to secure a successful regeneration and potentially to create a mixed forest.

At each site, the experiment was divided in a clearcut and a shelterwood treatment, which was further split into two treatments; with and without mechanical site preparation (MSP) prior to planting. The first assessment of the experiment was conducted in 2010, revealing that on the southern sites, Norway spruce had become the dominant species, while mixed-species stands were still achievable on the central and northern sites. Now, fifteen years later, twelve sites were possible to re-measure, with registrations of tree species composition, stem density and basal area for evaluation of a mid-rotation result. The experimental sites were divided regionally into southern, central- and northern Sweden. Further stand development was simulated using StandWise, Heureka, to estimate stand growth and yield until final harvest.

In accordance with the findings fifteen years ago, the southern sites had developed into Norway spruce monocultures. Whereas the central sites developed into mixed pine and spruce forest. As for production, both clearcut treatments (with and without MSP) exhibited higher basal areas compared to the two shelterwood treatments on the southern and central sites. On all northern sites, the shelter trees of pine still remained for unknown reasons, leading us to exclude those sites for production comparisons. This highlights the need of more frequent monitoring and management in other regeneration measures compared to planting on clearcuts. Our findings suggest that shelterwood and planting strategies can effectively promote the development of mixed forests.

**Keywords:** Conifer mixture, shelterwood, regeneration methods

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