Natural resources and bioeconomy studies 77/2023

Climate resilient and sustainable forest management

IBFRA Conference 28-31 August 2023 Book of Abstracts

Raisa Mäkipää and Kati Berninger (eds.)

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Abstract

Raisa Mäkipää[1] and Kati Berninger[2]

[1] Natural Resources Institute Finland
[2] Tyrsky Consulting

The 20th IBFRA (The International Boreal Forest Research Association) conference held in Helsinki Finland 28-31 August 2023 brings together researchers, companies, policy makers and members of the civil society. The conference main theme is Climate resilient and sustainable forest management. The abstracts of the conference are in this publication.

Keywords: boreal forest, research, climate, resilience, sustainable forest management

Contents

1. Foreword

Welcome to the 20th International Boreal Forest Research Association Conference in Helsinki. It is a great pleasure to welcome all of you to the IBFRA2023 conference on-site in Helsinki as well as virtually. The boreal forest, which is the second most extensive terrestrial biome on earth, is experiencing environmental changes at rates that are unprecedented. Changing climate is increasing risks for major disturbances such as wildfires or insect outbreaks. Many boreal ecosystems are shifting to new ecological states, affecting the people who are relying on these ecosystems for subsistence living, cultural practices, economic development or climate stability. Hence, together with the eminent scientific steering board, we have identified "Climate Resilient and Sustainable Forest Management" as the topic of this important milestone of our research association.

We are proud that highly relevant and scientifically challenging research contributions covering wide spectrum of topics from understanding linkages between ecosystem processes and management to decision support tools and solutions for sustainable forestry will form the heart of our conference. The IBFRA2023 conference www.ibfra2023.org will offer over 200 presentations in parallel sessions together with poster sessions and keynote speeches as well as networking opportunities, science-policy-practice dialogue, demonstrations, excursions, and social events. World-leading and early-career scientists will examine the critical ecosystem functions and services of the boreal forests, identify their risks, and propose pathways to protect them.

The organizing body - the International Boreal Forest Research Association (IBFRA, www.ibfra.org)- is a global organization focused on advancing research and knowledge about the boreal forest ecosystem. IBFRA's vision is to facilitate interdisciplinary collaboration and cooperation to promote sustainable management and conservation of the boreal forest. By fostering research partnerships, exchanging scientific knowledge, and supporting evidence-based policy recommendations, IBFRA strives to address the complex challenges facing the boreal forest.

IBFRA's goals include promoting research collaboration, knowledge exchange, policy support, capacity building, and conservation efforts. Through international partnerships – e.g., with the International Union of Forest Research Organizations (IUFRO), IBFRA encourages scientists, researchers, policymakers, and stakeholders to work together in studying and preserving the unique boreal forest. By disseminating valuable information, organizing conferences and webinars, and engaging with policymakers, IBFRA aims to bridge the gap between research and policy, influencing decision-making processes for sustainable forest management. Additionally, IBFRA focuses on capacity building by supporting education and professional development opportunities, contributing to the expertise needed to address the complex issues of the boreal forest. With its commitment to collaboration, knowledge dissemination, and conservation efforts, IBFRA plays a vital role in ensuring the long-term viability and ecological integrity of the boreal forest.

We thank all of you for contributing to this goal, by presenting your abstracts and keynotes, discussing the scientific findings, participating in panels or by establishing new collaborations to enhance relevant research activities and to spread the insights in resulting publications and policy briefs. We would also like to express our gratitude to the scientific committee for

reviewing the abstracts, to all the generous sponsors for supporting this event and to everyone else who contributed to making this conference possible. The conference is hosted by the Natural Resources Institute Finland (www.luke.fi), SOMPA project (www.luke.fi/sompa) of the Strategic Research Council, and UNITE Research Flagship (www.uniteflagship.fi) of the Research Council of Finland.

We wish you all a very insightful and stimulating event, encouraging all of us to join our efforts in identifying future pathways for the critical role of the boreal forests!

Raisa Mäkipää (Conference Chair, IBFRA Vice President)

Florian Kraxner (IBFRA President)

2. Novel soil management practices – key for sustainable bioeconomy and climate change mitigation (SOMPA project)

SOMPA project (2018-2023) has studied ecologically and economically sound methods to manage forests and croplands on peat soils, which are currently a large source of greenhouse gas (GHG) emissions. Overall aim of the project is to develop and test sustainable management methods that mitigate GHG emissions and contribute on climate targets of the land-use sector. Below we review the key research results and impacts related to forestry.

The SOMPA project established new experimental sites of continuous cover forestry (CCF) in drained nutrient-rich peatland forests in Finland. We monitored the hydrology (e.g. water table level, soil temperature), soil greenhouse gas exchange (heterotrophic respiration (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions) as well as natural regeneration of the forests managed by selection harvesting, where single trees or small tree groups, mainly from the dominant canopy layer of the stand are removed. After harvesting, the evapotranspiration of the vegetation decreased and during the late growing season, when the site´s moisture conditions are most critical for the forest growth, the average water level raised slightly by 2-18 cm depending on weather conditions and the evapotranspiration capacity of the living tree stand left on site. However, the water table did not raise so high in any experiment that it would significantly disturb stand growth. Selection harvesting seemed to have slightly decreasing effect on the respiration in peat (See Figure 1). However, the surface peat layer, which contribute a largest proportion of the soil CO_2 emissions, is susceptible to decomposition also after selection harvesting because it stays above water table level. After selection harvesting, CH_4 and N_2O emissions increase slightly. The CH_4 emissions increase especially if the site was already moist before harvesting, i.e., the mean water level was at a depth of less than 40 cm. The risk of N_2O emissions is greatest in nitrogen-rich sites and after intensive harvesting. However, overall, continuous cover forestry improved the soil carbon balance and resulted in significantly lower net emissions than those after clear-cutting (Figure 1).

The seedling inventories showed that the nutrient-rich peatland sites regenerate with spruces and Downy birch well. The seedling material established already before selection harvesting is of great importance. Some of those seedlings are destroyed during harvesting, but they are compensated by new seedlings after harvesting. The important factors affecting the seedling are the competition intensity of the overstory trees and the characteristics of the microsite structures on soil surface such as the coverage of *Sphagnum* moss vegetation favorable for seed germination. Overall, high regeneration potential promotes the transfer from even-aged to uneven-aged stand structure and thus the feasibility of CCF on nutrient-rich peatlands.

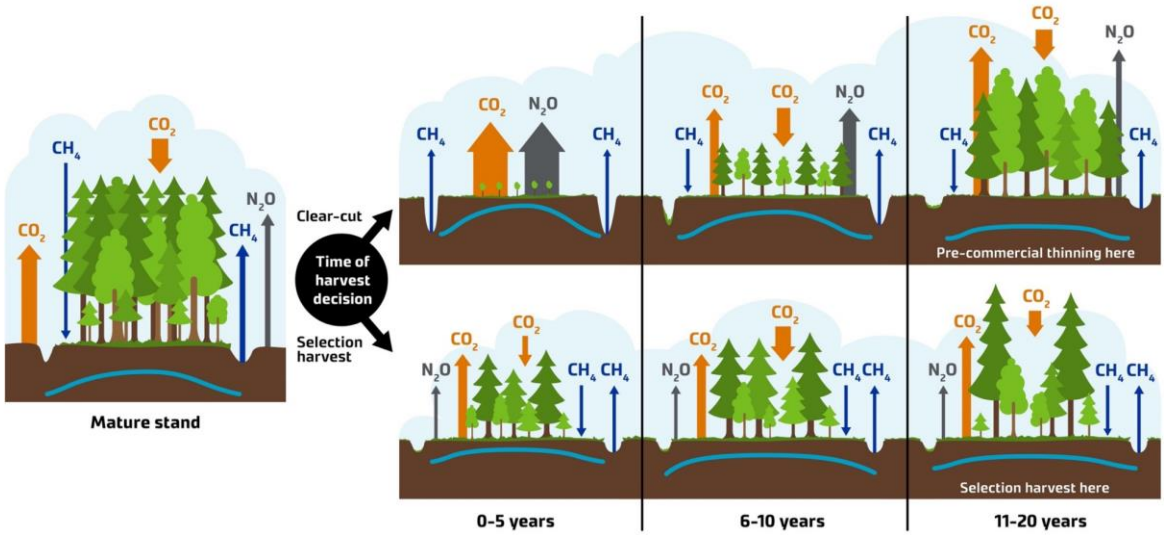

Figure 1. The height of the groundwater level and the emissions and sinks of greenhouse gases, i.e. carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) in drained nutrient-rich spruce peatlands of different ages after clear felling and selection harvesting.

The SOMPA project examined the profitability of continuous cover forestry (CCF) in peatland forests. According to the research results, mature Norway spruce-dominated peatland forests seem to be ideal for CCF with selection harvest. The simulations showed that the profitability of CCF was higher than that of rotation forestry (RF) utilizing final felling. The results can largely be explained by CCF not accumulating any silviculture expenses, because regeneration was natural and there was no need for soil improvement, ditch network maintenance or tending of a sapling stand, unlike in RF. What is more, RF required decades before harvest revenues were obtained after forest regeneration, reducing profitability. The best financial results in CCF were achieved when the thinning interval was 15 years and trees were thinned so that the post-harvest basal area was 10 square meters per hectare (90–100 cubic meters per hectare). Many of the management options for selection cuttings produced almost equally high financial results. The results also showed that no ditch network maintenance (DNM) operations are needed if enough trees are left in the forest in CCF. In addition, we examined the financial performance of joint production of timber and carbon sequestration. The cost of additional ton of CO_2 fluctuated between €30 and €39.5/tCO_2, depending on the carbon price applied for a private forest owner (€25-€75/tCO_2).

The SOMPA project formulated future scenarios for Finnish forests as well as estimated future development of GHG exchange between forest ecosystem and atmosphere by running forest simulator MELA with soils models for both mineral and peatland soils. Our scenarios included BAU (business as usual) and CCF (continuous cover forestry, where clear-cuts were not allowed on nutrient rich drained peatlands). Simulations showed that the management scenario (CCF) that avoided clear-cutting on nutrient-rich drained peatlands produced approximately 1 Tg CO_2 eq. higher carbon sinks annually compared to the BAU at equal harvest level for Finland including all forest lands. This emission reduction can be attributed to the maintenance of higher biomass sink and to the mitigation of soil emissions from nutrient-rich drained peatland sites. Larger biomass sink with the CCF scenario was attributed to the fact that there were less seedling stands compared to BAU. Lower soil emissions on CCF

compared to that of BAU were attributed to the avoidance of significant clear-cut related emissions on nutrient-rich drained peatlands.

Climate change impacts of CCF appear beneficial in the forest ecosystem, including forest and soil carbon pools, but impacts of CCF on wood substitution should be estimated along with forest carbon pools. Substitution impacts describe how much increased wood use would decrease or increase greenhouse gas emissions in the technosystem when replacing non-renewable alternatives. We estimated substitution impacts of a scenario based on CCF and BAU. The harvesting levels and the shares of log and pulp wood in the two scenarios are nearly identical, thus, the substitution impacts of the scenarios are nearly identical. There were only small differences between wood product carbon sinks of the two scenarios. Based on the results of this study, climate change impacts of CCF are not compromised by substitution impacts.

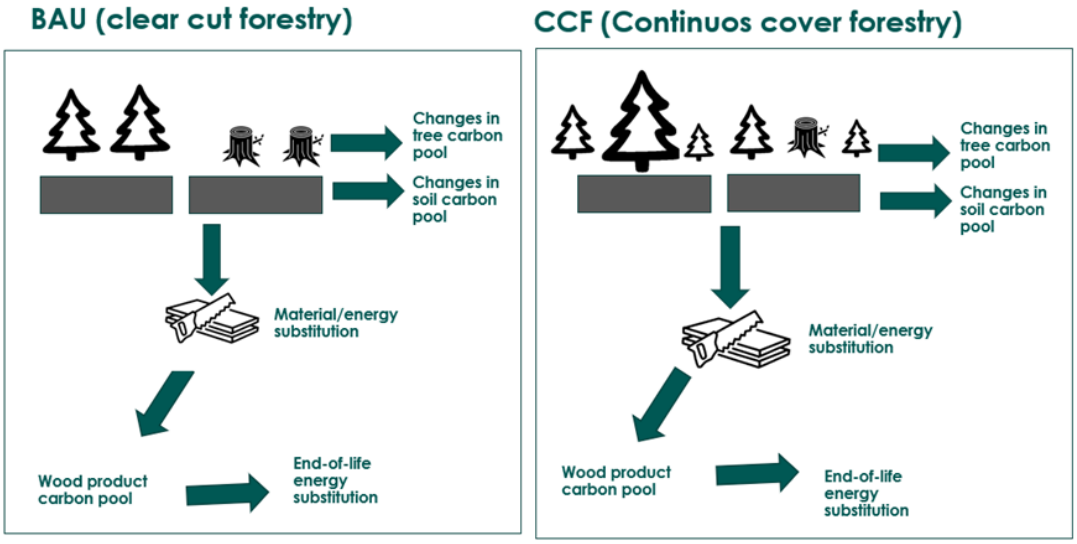

Figure 2. Framework on assessing climate change impacts of CCF (continuous cover forestry on fertile drained peatlands) and BAU scenarios.

During the project, the greenhouse gas emissions from the use of peatlands and their importance for the Finnish emissions have come up in the social debate. SOMPA project has been an important catalysator of the discussion and publicity of these issues. SOMPA has published several policy briefs with policy recommendations for national or EU agricultural and forest policy. The project has had an impact on the new Finnish forestry subsidy system and the new CAP regarding peatlands. SOMPA project has had a continuous dialogue with forest industry. SOMPA project has had a strong impact on the Finnish forest management guidelines. CCF is now increasingly being used on peatland forests.

SOMPA website: https://projects.luke.fi/sompa/en/

3. Address from UNITE Flagship

IBFRA 2023 Conference has been co-organized by UNITE Flagship, which is a Finland-based competence centre within the Research Council of Finland's Flagship Programme, aiming at strong economic and societal impact of cutting-edge science. UNITE stands for "*Forest-Human-Machine Interplay – Building Resilience, Redefining Value Networks and Enabling Meaningful Experiences*". UNITE is coordinated by the University of Eastern Finland (UEF) and partnered by Finnish Geospatial Institute (FGI) in the National Land Survey of Finland, Natural Resources Institute Finland (Luke) and Tampere University (TAU). The Flagship features tens of business, policy, and non-profit collaborators in Finland and beyond.

UNITE paves the way towards a biosociety, in which managing, utilizing, and interacting with forests are climate-smart, resource-efficient, multifunctional, and humane, simultaneously enhancing forest resilience, sustainable provisioning of versatile ecosystem services, adaptation to and mitigation of climate change, and meaningful living. UNITE enhances the interplay between forests, humans, and machines, and provides science-based know-how, novel solutions and tools for enhanced management and utilisation of and joyful interaction with forests.

Through breakthroughs, landmark science, and broad scientific and societal impact, UNITE contributes to society, culture, industry and policy, under four interrelated thematic areas (i): Disruptive technologies for capturing forest ecosystem structure and functioning, (ii) Agile knowledge creation from the forest data, (iii) Smart decision support for human actions in space and time, and (iv) Gameful forest interaction for meaningful experiences and practices. The above areas have served as the basis for the IBFRA 2023 scientific subthemes. Moreover, several UNITE scientists have participated the IBFRA 2023 Scientific Organizing Committee and prepared the interactive Science-Policy-Practice afternoon for Wednesday, 30th August.

UNITE Flagship is honored of the opportunity to collaborate with IBFRA in organizing this conference and looks forward to deepening interactions with the IBFRA community in topics of mutual interest.

Heli Peltola
Professor, University of Eastern Finland
UNITE Director

Teppo Hujala
Professor, University of Eastern Finland
UNITE Impact Coordinator

More information about the UNITE Flagship:
https://youtu.be/529YMKgR6HY | https://uniteflagship.fi/

4. Regenerative forestry actions aiming to make Finnish forests increasingly vibrant and diverse

Timo Lehesvirta (Metsä Group, event sponsor), invited talk in session on 'Knowledge exchange towards sustainability transformation in forests', Wednesday 30.8.2023 at 13:15–15:00.

Metsä Group launched in March 2023 regenerative forestry principles aiming to enhance the state of nature by 2030. Metsä Group is a Finnish forest industry group focusing its operations in Finland providing wood supply and forest services to owner-members of its parent company Metsäliitto Cooperative. Regenerative forestry disconnects the economic growth and biodiversity loss including numerous measures that enhance biodiversity and the resilience of forests as the climate changes.

Regenerative forestry is based on the industrial use of native tree species. The goal is to diversify tree species composition and thus halt biodiversity loss. In forests with a diverse range of species and age classes, competition between species prevents the success of species cause forest damages. As the lack of decaying wood continues to be the most common single cause for the endangerment of forest species, regenerative forestry accelerates the creation of decaying wood. To secure the living conditions of species that inhabit ecologically valuable habitats, special attention is paid for biodiversity hot spots such as herb-rich forests, esker forest habitats and fire habitats. Also, water protection is being developed on peatlands.

The goal in regenerative forestry is to manage ecosystem services holistically and develop forest management to allocate different ecosystem services based on set targets. The goal is to develop monitoring and follow-up to cover, in addition to wood production, biodiversity and versatile ecosystem services such as carbon sinks and nationally important services from water resources to pollinators.

Metsä Group Plus, a new forest management model, is one of the key practical measures for achieving targets of regenerative forestry. Under Metsä Group Plus model, more retention trees and high biodiversity stumps are left per hectare of forest during felling than certification systems require. Also the burning of retention trees will be increased and the highest level requirements of buffer zones around waterbodies is implemented. Other actions include sparing sparsely occurring broadleaved trees in wood supply in Finland. Metsä Group also helps to target FSC protection to the most valuable sites for nature through the Habitat Site Service.

The goal is to enhance make Finnish forests increasingly vibrant and diverse by 2030 as part of the strategy of regenerative forestry. The effects of regenerative forestry are measured using the best available information based on science-based data. Metsä Group's forest services are being developed in versatile manner. We are seeking new wide ranging cooperation to enhance biodiversity and to develop measurement of our actions.

The data measured about the impacts of the regenerative forestry will be utilized in development projects to build next generation evidence of impacts on products and value chains. In this case, indicators that tell about biodiversity and ecosystem services play a key role.

5. Compiling Stakeholder views on forest soil health

Tiina M. Nieminen and Raisa Mäkipää (BENCHMARKS project, event sponsor), contribution to 'Interaction and co-development' session on Wednesday 30.8.2023 at 15:30–17:15

Soil health can be defined as the actual capacity of soil to provide ecosystem services[1]. The Soil Health and Food Mission assessment highlights also the support actions needed to improve this capacity and to ensure its continuity. Monitoring of soil health is pointed out as a key component to demonstrate the future improvement to be gained by the Mission and other EU Green Deal policies.

Monitoring of European soils must be based on relevant indicators to be able to provide coherent and reliable information on the state and trends of soil health. To meet this goal, the Horizon Europe Soil Mission project BENCHMARKS "Building a European Network for the Characterisation and Harmonisation of Monitoring Approaches for Research and Knowledge on Soils" collaborates with stakeholders to co-develop and evaluate a multi-scale and multi-user focused monitoring framework. This framework aims to provide a soil health index for benchmarking, using indicators that are pertinent to reveal changes in time, applicable also to forest land and logistically feasible.

In context of the IBFRA Stakeholder Day BENCHMARKS aims to co-develop forest-focused indicators with the participating stakeholders, as well as to evaluate the forest-related indicators provided by the EU Soil Mission. Since the indicators need to meet the requirements set by the Soil Health & Food Mission Objectives, they should take into consideration 1) nutritional and hydrological quality of forest soil, 2) soil biota as a supporter of forest soil functions, 3) organic carbon content of forest soil, 4) the surface area of sealed soil and its share in relation to forest land, 5) pollutant content and pollutant's bioavailability in soil, 6) condition of forest vegetation, forest management regimes and prevalence of such soil characteristics which pose a risk of high soil erosion and/or soil compaction. Repeated observations of indicators according to a harmonized methodology are needed to quantify changes in time, such as the success of restoration actions on degraded forest land.

[1] European Commission, Directorate-General for Research and Innovation, Veerman, C., Pinto Correia, T., Bastioli, C., et al., Caring for soil is caring for life: ensure 75% of soils are healthy by 2030 for healthy food, people, nature and climate: interim report of the mission board for soil health and food, Publications Office, 2020, https://data.europa.eu/doi/10.2777/918775

6. Conference programme

Check the most recent updates of the programme from *www.ibfra2023.org*

Monday 28.8.2023

Plenary session (room Latva & Oksa)

10:00–10:20 Conference opening, IBFRA Vice President and Conference Chair Raisa Mäkipää, IBFRA President Florian Kraxner, and IUFRO Executive Director Alexander Buck

10:20–11:00 Keynote: Geoengineering peatlands – degradation, restoration and enhancement of the peatland carbon store, Martin Evans (University of Manchester)

11:05–11:25 Synergies among multiple ecosystem services in five European countries, Silvio Schueler (Austrian Research Centre for Forests BFW)

11:25–11:45 Break

11:45–13:15 Parallel Sessions 1.1 and 1.2

Session 1.1 Peatlands and emissions, chair: Scott Davidson (room Latva)

1.1.1 Dynamics of CO_2 fluxes measured with the eddy covariance technique 1-7 years after a clear-cut in four forest sites in Finland, Lohila Annalea

1.1.2 Ecosystem-scale observations of CO_2, CH_4 and N_2O fluxes at a drained boreal peatland forest after clear-cutting, Olli Peltola

1.1.3 Peat respiration in drained peatland forests under varying tree harvest regimes, Aino Korrensalo

1.1.4 Fine root production in boreal peatland forests: effect of tree species, climate and site nutrient regime, Wei He

1.1.5 Implementation and evaluation of Landscape-DNDC model for forestry management methods at a nutrient-rich peatland site in southern Finland, Ahmed Shahriyer

Session 1.2 Multiobjective optimization, chair: Aapo Rautiainen (room Oksa)

1.2.1 Digital twin enabled forest management with multiobjective optimization, Bekir Afsar

1.2.2 MultiForestOpt: simplifying multi-objective optimization for forest planning and scenario analysis, Kyle Eyvindson

1.2.3 Decision Support for Boreal Forest Planning using Interactive Multiobjective Optimization, Bhupinder Singh Saini

1.2.4 Decision support for sustainable forest harvest planning using multiobjective optimization and the value of information, Babooshka Shavazipour

1.2.5 Optimal forest rotation under carbon pricing and forest damage risk, Tommi Ekholm

13:15–14:30 Lunch

14:30–16:00 Parallel Sessions 2.1 and 2.2

Session 2.1 Hydrology and its impacts, chair: Martin Evans (room Latva)

2.1.1 Restoration of natural hydrology in forests, Oscar Alexander Andersson

2.1.2 Ecohydrological modelling for boreal forestry, Samuli Launiainen

2.1.3 Precipitation and beavers contribute to an increase in water color and iron level in boreal lakes, Clarisse Blanchet

2.1.4 Short-term effect of thinning on carbon dioxide and water vapour fluxes in a boreal pine forest, Toprak Aslan

2.1.5 Soil GHG dynamics after water level rise – impacts of selection harvesting in peatland forests, Mikko Peltoniemi

Session 2.2 Habitats and biodiversity, chair: Jalene LaMontagne (room Oksa)

2.2.1 Links between red wood ant (Formica rufa-group) mound densities and past/present forest management in Sweden, Emil Andersson

2.2.2 Improving forest habitat for biodiversity: what influences deadwood amount in European forests? Andrey Lessa Derci Augustynczik

2.2.3 Woody debris patterns and processes in a boreal forest can be restored by prescribed burning and variable retention, Ekaterina Shorohova

2.2.4 Combining experimental and temporal observation data to identify species interactions in colonization and extinction of wood-decay fungi, Hedvig Nenzen

2.2.5 Changed species colonization-extinction dynamics in plant communities given changed forest and climate conditions, Laura Chevaux

16:00–16:30 Coffee

16:30–18:00 Parallel Sessions 3.1 and 3.2 (session 3.2 will end at 17:30)

Special session 3.1 Functioning and sustainable management of boreal peatland forests, chairs: Mikko Peltoniemi, Raisa Mäkipää (room Latva)

3.1.1 Soil microbial diversity and functioning of boreal managed peatlands, Invited speaker Petr Baldrian (Institute of Microbiology of the Czech Academy of Sciences)

3.1.2 The effect of two different cutting methods on net CO_2 exchange in a nutrient-rich peatland forest, Mika Korkiakoski

3.1.3 Peatland forest CO_2 fluxes and their controls: Does continuous cover forestry help to reduce soil emissions? Helena Rautakoski

3.1.4 Mosses as biofilters for ditch methane emissions from forestry drained peatlands, Antti J Rissanen

3.1.5 Regeneration of drained boreal Norway spruce peatland sites after selection harvesting targeting to continuous cover forest management (CCF), Sakari Sarkkola

Session 3.2 Forest monitoring systems, chair: Annika Kangas (room Oksa)

3.2.1 Quantifying the value of using detailed forest inventory information in a Norwegian context, Olha Nahorna

3.2.2 Data assimilation for forest inventory: first Norwegian experiences, Svetlana Saarela

3.2.3 The Forest Observation System – a global harmonised in-situ data repository for forest biomass maps validation, Dmitry Schepaschenko

3.2.4 Age-dependent stand biomass models based on the Finnish National Forest Inventory data, Anna Repo

19:00–20.30 Reception at Helsinki City Hall (Pohjoisesplanadi 11-13), hosted by City of Helsinki.

Tuesday 29.8.2023

9:00–10:30 Parallel Sessions 4.1 and 4.2

Special session 4.1 Managing for diversity I: A call for a better understanding of linkages between forest structure, biodiversity and carbon cycle, chairs: Martin Forsius, Niko Kulha, Minna Pekkonen, Junior A. Tremblay (room Latva)

4.1.1 Impacts of future forest use on biodiversity, ecosystem services and climate, Tord Snäll (Swedish University of Agricultural Sciences)

4.1.2 Integrated biodiversity conservation and carbon sequestration in the changing environment, Annikki Mäkelä (University of Helsinki)

4.1.3 Spatio-temporal variability of the predicted impacts of climate change on boreal biodiversity, Junior A. Tremblay (Environment and Climate Change Canada & Université Laval)

4.1.4 Biodiversity and climate synergies in managed boreal forests achieved by protecting carbon storages, not sinks, Ninni Mikkonen

Session 4.2 Economic and societal perspectives, chair: Francisco X. Aguilar

4.2.1 Contribution of the Norwegian forest sector in climate change mitigation under alternative production scenarios, Maarit Kallio

4.2.2 Substitution and carbon storage impacts of harvested wood products - Effects of increased cascading with different market responses, Janni Kunttu

4.2.3 EU Forest Area Protection: Reduced Harvest Potential and Unintended Displacement Effects, Pekka Lauri

4.2.4 CO_2 removal technologies and the optimal role of global forests in a welfare-maximizing climate policy, Aapo Rautiainen

4.2.5 Importance of ownership type on forest management, Endre Hofstad Hansen

4.2.6 Carbon dynamics modeling for woody biomass recovered from wildfire fuel management to the bioeconomy, Sheng Xie

Coffee 10:30–10:50

10:50–12:20 Parallel Session 5.1 and 5.2

Session 5.1 Managing for diversity II: A call for a better understanding of linkages between forest structure, biodiversity and carbon cycle, chairs: Martin Forsius, Niko Kulha, Minna Pekkonen, Junior A. Tremblay (room Latva)

5.1.1 Ecosystem-based management as a reference for sustainable forestry in Fennoscandia, Jenni Nordén

5.1.2 How do functional traits, species properties and climate influence tree mortality across Europe? Niko Kulha

5.1.3 Forest structure and naturalness in the Finnish national forest inventory, Mari Myllymäki

5.1.4 The carbon balance of boreal old-growth forests in relation to lichen diversity, Anu Akujärvi

5.1.5 Future wood demands and ecosystem services trade-offs: A policy analysis in Norway, Marta Vergarechea

5.1.6 Enhancing resilience of boreal forests through management under global change: A review, María Triviño

Session 5.2 Perceptions and acceptance, chair: Lauri Hetemäki (room Oksa)

5.2.1 Perceptions of forest professionals on managing forest disturbance to enhance forest resilience, Laura Nikinmaa

5.2.2 Norwegian and Swedish public preferences for forest management practices underpinned by the self-construction of climate change, Dohun Kim

5.2.3 From timber to carbon: stakeholder acceptance of policy measures supporting forest management transition in Finland, Samuli Pitzén

5.2.4 Forest professionals' perceptions of uncertainty in forest planning, Adriano Mazziotta

5.2.5 Forest owners' willingness to implement measures promoting water protection in boreal peatland forestry, Jenni Miettinen

5.2.6 Barriers and enablers for climate and biodiversity-smart forest management in Europe, Diana Feliciano

12:20–13:30 Lunch

13:20–14:00 Poster presentations (P1.1-P1.34, room Kelo) & coffee

14:00–15:15 Parallel Sessions 6.1 and 6.2

Session 6.1 Sustainable use of forests, chair: Kyle Eyvindson (room Latva)

6.1.1 Exploring ecological drivers and responses of biodiversity to improve simulation studies, Juliette Hunault-Fontbonne

6.1.2 Safe operating boundaries for boreal forest harvesting, Mikko Mönkkönen

6.1.3 Should I spare or should I share? A multifunctional assessment of Triad management in Finnish boreal forest landscapes, Rémi Duflot

6.1.4 Review of research on forestry measures to sustain biodiversity in boreal forest ecosystems, Ane Christensen Tange

6.1.5 Input data resolution affects the quality of conservation prioritization, Topi Tanhuanpää

Session 6.2 Climate-ecosystem interactions, chair: Florian Kraxner (room Oksa)

6.2.1 Forest carbon stock budget development following extreme drought-induced dieback of coniferous stands in Central Europe, Emil Cienciala

6.2.2 Disentangling the net climatic effects of moose browsing in early successional boreal forests, Xiangping Hu

6.2.3 Reduction of land surface temperature associated with forest management in Fennoscandia, Bo Huang

6.2.4 Understanding the drivers and trends of terrestrial ecosystem CO_2 fluxes across the boreal biome, Anna-Maria Virkkala

15:15–15:30 Break

15:30–17:00 Parallel Sessions 7.1 and 7.2

Special session 7.1 Radiation regime of boreal forests – measurements and models, chairs: Aarne Hovi, Daniel Schraik (room Latva)

7.1.1 Fine-spatial UAV-albedo in boreal forests, Eirik Næsset Ramtvedt (Norwegian University of Life Sciences, invited speaker)

7.1.2 Proximal imaging of small trees under ambient greenhouse conditions (PIA), Jon Atherton

7.1.3 Leaf chlorophyll and carotenoid contents of European Aspen and their assessment by airborne imaging spectroscopy, Sarita Keski-Saari

7.1.4 Revealing fine-scale variability in boreal forest temperatures using a mechanistic micro-climate model, Joonas Kolstela

Session 7.2 Forest growth and regeneration, chair: Annikki Mäkelä (room Oksa)

7.2.1 Are fast growth and drought tolerance two opposed properties in conifers? Scots pine case, M Rosario García-Gil

7.2.2 Forest management in British Columbia's boreal forest: the disconnect from traditional land use, Christopher Hawkins

7.2.3 How does a changing climate influence seed production in boreal conifers? Findings from observational and experimental approaches, Jalene LaMontagne

7.2.4 Fast recovery of suppressed Norway spruce trees after selection harvesting on a drained peatland forest site, Aleksi Lehtonen

7.2.5 The quasi-pipe (qPipe) model – a convenient allometry for estimating the amount of leaves per tree, Akihiro Sumida

7.2.6 Masting in forests: a playful introduction, Lea Végh

17:00–18:00 Afternoon tea with posters

Wednesday 30.8.2023

Plenary Session (room Latva & Oksa)

9:00–9:40 Keynote: How to find sustainable management solutions within a changing climate? – Decision support tools for forest planning and analysis, Karin Öhman (Swedish University of Agricultural Sciences)

9:45–10:05 Dealing with natural hazards in decision support, Annika Kangas (Natural Resources Institute Finland)

10:05–11:15 Poster presentations (P2.1–P2.34, Kelo) & coffee

10:45–12:00 Parallel Sessions 8.1 and 8.2

Session 8.1 Modelling and managing damage risks, chair: Katharina Albrich (room Latva)

8.1.1 Optimizing the regeneration of spruce-dominated stands infected by Heterobasidion root rot, Eero Holmström

8.1.2 Modeling feedbacks between fire and forest management at the landscape scale under historical and future climate scenarios, Jocelyne Laflamme

8.1.3 Improving the risk modelling of wind and snow damage for supporting decision making in forest planning in Sweden, Emanuele Papucci

Session 8.2 Laser scanning and point clouds I, chair Matti Maltamo (room Oksa)

8.2.1 Detection of tree growth and changes in tree and forest structures by utilizing terrestrial laser scanning point clouds, Ville Luoma

8.2.2 Monitoring Species-specific Response to Competition at Tree-level Using Multisensorial Point Cloud data in Boreal Forests, Ghasem Ronoud

8.2.3 Estimating the amount and distribution of forest biomass burned in controlled burnings with bitemporal terrestrial laser scanning, Noora Tienaho

12:00–13:15 Lunch & posters

13:15–17:15 Parallel Sessions 9.1 and 9.2, 10.2 and 11.2 (end at 16:45)

Session 9.1 Forest science-policy-practice interactive afternoon – Knowledge exchange towards sustainability transformation in forests (room Latva)

- Challenges of climate resilience in forest management (Raisa Mäkipää, Natural Resources Institute Finland, Conference Chair, IBFRA Vice President)
- Climate change and forest management driving forest composition, structure and productivity (Florian Kraxner, IIASA, IBFRA President)
- TEAMING UP 4 FORESTS – A platform for science and business to collaborate on tackling climate change (Alexander Buck, IUFRO Executive Director)
- Biodiversity roadmap developed by wood processing industry (Anniina Kostilainen, The Finnish Sawmills Association, Manager of Public Relations)
- Regenerative forestry actions aiming to make Finnish forests increasingly vibrant and diverse (Timo Lehesvirta, Metsä Group)
- Interactive panel discussion on how to enhance researcher-practitioner interaction towards more agile research impact (Moderators: Teppo Hujala, University of Eastern Finland, and Sari Pynnönen, Natural Resources Institute Finland)
- Closing: Raisa Mäkipää

15:00–15:30 Coffee

Sensor technology and forest gamification demos

- Intro: Opportunities of upcoming smart sensors in forest data acquisition (Antero Kukko, Finnish Geospatial Research Institute)
- Getting familiar and trying out the following technologies:
    - Gamified point cloud collection from the environment; Timo Nummenmaa (Tampere University) and Tuomas Yrttimaa (University of Eastern Finland)
    - Engaging with climate change in virtual reality; Daniel Fernández Galeote (Tampere University)
    - Sustainability supply chain educational game; Ville Uhlgren (Tampere University)
    - Demonstration of greenhouse gas measurements with portable gas analyzer; Luke team
    - Backpack laser scanner; Antero Kukko (Finnish Geospatial Research Institute) and Mikko Vastaranta (University of Eastern Finland)
    - Single-tree information system Metsäkanta.com; FGI team & Ville Kankare (University of Eastern Finland)
- Interactive ideation and feedback (Moderators: Tuulikki Halla, University of Eastern Finland, and Tiina M. Nieminen, Natural Resources Institute Finland)
- How to enhance research impact with interaction? Reflections on the demo experiences? How to assess soil properties and health?
- Closing

Session 9.2 Laser scanning and point clouds II, chair: Ville Luoma (room Oksa)

9.2.1 Creating countrywide tree maps with airborne laser scanning and ground measurements with a bootstrapping approach, Joel Kostensalo

9.2.2 The same airborne laser scanning based model of a stand attribute can be used in forests treated with different silvicultural management systems, Matti Maltamo

9.2.3 Understanding tree growth allometry using multisensorial point clouds, Maryam Poorazimy

9.2.4 Developing nonlinear additive tree crown width models based on decomposed competition index and tree variables, Siyu Qiu

Session 10.2 Evaluating damage risks to forests, chair: Juha Honkaniemi (room Oksa)

10.2.1 Effects of spatial arrangement on disturbance risk under two alternative management strategies, Katharina Albrich

10.2.2 Resilience to wind disturbance in production forests: a modelling case study from south-western Finland, Jonathan Holder

10.2.3 Modeling risks of climate-driven wildfires in boreal forest: the FLAM approach, Shelby Corning

10.2.4 Modeling predisposition of boreal Norway spruce forests to bark beetle infestations, Päivi Lyytikäinen-Saarenmaa

15:15–15:45 Coffee

Session 11.2 Ecosystem services under pressure, chair: Karin Öhman (room Oksa)

11.2.1 Combining scientific and local knowledge improves the evaluation of future forest ecosystem services, Isabella Hallberg-Sramek

11.2.2 CLIMB-FOREST project: Holistic account of forest climate effects from afforestation and modified management, Adam Kristensson

11.2.3 Future development of European forests reveals limited synergies and trade-offs among ecosystem services, Jouni Sorvari

11.2.4 Consequences of moose browsing on timber production, management and multiple societal returns, Hanne K. Sjølie

Thursday 31.8.2023

Plenary session (room Latva & Oksa)

9:00–9:40 Keynote: Closing the loop: Contributions of remote sensing to characterizing post-disturbance forest recovery in boreal forests, Joanne White (Canadian Forest Service & Natural Resources Canada)

9:40–10:45 Poster presentations (P3.1 – P3.33, room Kelo) & coffee

10.45–12:20 Parallel Sessions 12.1 and 12.2

Session 12.1 Mapping disturbance agents, chair: Joanne White (room Latva)

12.1.1 Using high-resolution satellite stereo imagery for mapping boreal forest fire fuel loads, Ranjith Gopalakrishnan

12.1.2 Future Arctic (Wild)Fires, Jessica McCarty

12.1.3 Mapping wind vulnerability in Norwegian forests under selected management scenarios with ForestGales, Morgane Merlin

12.1.4 Mapping the stand-level risk of spruce root rot in Finland using harvester data, Susanne Suvanto

12.1.5 Wind damage detection in Nordic forests by 3D reconstruction of very high resolution optical satellite imagery, Peter Zubkov

Session 12.2 Technological solutions and innovations, chair: Heli Peltola (room Oksa)

12.2.1 Identifying potential locations for bilberry picking with remote sensing, in-situ field data and phone-application, Inka Bohlin

12.2.2 Using a location-based game for forest planning purposes, Philip Chambers

12.2.3 Development and assessment of a system for digitalized follow-up of nature and culture conservation measures at harvesting using harvester data, Maria Nordström

12.2.4 Predicting spatial and temporal variation in forest trafficability: Training a machine learning model against harvester-measured rolling resistance, Aura Salmivaara

12.2.5 Estimating the accuracy of smartphone app-based removals against actual wood harvesting data from clear cuttings, Ville Vähä-Konka

12:20–13:30 Lunch & posters

13:30–15:00 Parallel Sessions 13.1 and 13.2

13.1 Special session: Remote sensing of northern peatland, chairs: Miina Rautiainen, Iuliia Burdun (room Latva)

13.1.1 Understanding peatland green leaf phenology using readily-available smartphone photography, Scott Davidson (University of Plymouth, invited speaker)

13.1.2 Novel site type, nutrient-level and land use database of peatlands in Finland, Maarit Middleton

13.1.3 Quantifying wetness variation and drought-sensitivity of pristine aapa mires with Sentinel-2, Tytti Jussila

13.1.4 Detecting spatio-temporal patterns of wetness in restored peatlands with multi-scale remote sensing, Lauri Ikkala

13.1.5 Spectral properties of dominant Sphagnum moss species in boreal peatlands, Sini-Selina Salko

13.2 Carbon dynamics and mitigation, chair: Göran Ståhl (room Oksa)

13.2.1 Untapped Afforestation and Reforestation Potentials for Climate Mitigation in the Boreal Zone and Beyond, Florian Kraxner

13.2.2 A novel framework for assessing GHG mitigation and nature restoration policies in forestry under climate change, Mykola Gusti

13.2.3 Is current science able to reliably assess uncertainties of the budget of climatically active substances (CO_2, CH_4, N_2O) of Russian forests?, Anatoly Shvidenko

13.2.4 Improved forest management for increased carbon sequestration: an assessment of the most prominent approaches in Norway, Ignacio Sevillano

13.2.5 The effects of forest operations and silvicultural treatments on litter decomposition rate: a meta-analysis, Francesco Latterini

13.2.6 Improving the understanding of boreal forest carbon cycle dynamics using a model-data fusion approach, Tim Green

15:00–15:30 Coffee

15:30–17:00 Parallel Sessions 14.1 and 14.2

Session 14.1 Remote sensing, chairs: Miina Rautiainen, Iuliia Burdun (room Latva)

14.1.1 Calibrating model-based predictions of forest characteristics based on remotely sensed data, Göran Ståhl

14.1.2 Hyperspectral measurements in mapping biodiversity of trees – evaluation based on in situ and laboratory observations, Aarne Hovi

14.1.3 UAS-SfM-derived Terrain Models for Monitoring the Changed Flow Paths and Wetness in Minerotrophic Peatland Restoration, Lauri Ikkala

14.1.4 Modeling peatland site types and land use classes with machine learning and remote sensing, Jonne Pohjankukka

14.1.5 Linking field observations to Sentinel-2 data to quantify peatland ground vegetation phenology, Yuwen Pang

Session 14.2 Adapting to changing disturbances, chair: Susanne Suvanto (room Oksa)

14.2.1 Climate change and extreme events – modeling economic adaptation of forest enterprises through tree species selection at different spatial scales, Jasper M. Fuchs

14.2.2 Impact of adaptation strategies on disturbance risk from spruce bark beetle and potential trade-offs with timber production, Teresa Fustel

14.2.3 Changing disturbance regimes and forest landscapes in Fennoscandia, Juha Honkaniemi

14.2.4 The Last Tree Standing: Climate, stand and tree level effects on spruce survival during Ips typographus outbreak, Nataliya Korolyova

14.2.5 The impact of bark beetle outbreaks on forest soil carbon accumulation, Hyungwoo Lim

14.2.6 Analysis of bark beetle communites in snow-damaged trees - are snow damages catalysts for insect damage or merely providing valuable dead wood Markus Melin

19:30–11:30 Conference dinner at Restaurant Meripaviljonki (Säästöpankinranta 3)

Friday 1.9.2023

9:00–18:00 Excursions hosted by SOMPA & HoliSoils projects and ALFA wetlands project and Finnish Meteorological Institute

9:00–17:00 Meetings and workshops hosted by projects

7. Conference abstracts

7.1. Speakers

KEYNOTE SPEAKER

Geoengineering peatlands – degradation, restoration and enhancement of the peatland carbon store

Martin Evans, Jonny Ritson, Rebecca Self

Dept of Geography, University of Manchester, United Kingdom

Abstract

Peatlands are important carbon stores but across the globe peatland ecosystems have been significantly impacted by human activity in ways that reduce carbon storage potential or lead to the release of carbon from the long-term peatland store. Peatland restoration brings significant carbon benefits through 'avoided losses' and restoring the natural carbon sequestration function of the peatland. In the UK upland blanket peatlands have been severely degraded over the past 2-300 years by a variety of human impacts including industrial pollution, overgrazing and burning. In the past 20 years there have been extensive efforts to restore these landscapes. Because these peatlands are subject to active management there is the potential to optimise restoration approaches and vegetation management to maximise the carbon sequestration potential of the landscape.

Three approaches are currently being trialled. 1) Replacing manged heather burning with cutting and the production and reapplication of biochar to the moorland. 2) Short term application of gypsum to restored peatlands to mitigate the enhanced methane flux associated with raising of water tables and 3) re-establishment of sphagnum across the moors to mitigate methane fluxes in the longer term.

Early results suggest that biochar produced in controlled environments has higher yields and better stability than that produced by heather burning and also that establishment of sphagnum in open water is an important mechanism for mitigating methane fliux.

Restoring and recreating peatlands is central to efforts to mitigate climate change by working with natural processes. However, in heavily managed landscapes there is potential to think creatively about ways in which we can geoengineer these systems by maximising carbon sequestration. The challenge is to achieve these aims whilst protecting the wider benefits that peatland ecosystems deliver to society.

KEYNOTE SPEAKER

Closing the loop: Contributions of remote sensing to characterizing post-disturbance forest recovery in boreal forests

Joanne White

Canadian Forest Service, Canada

Abstract

The success and rate of forest regeneration has consequences for sustainable forest management, climate change mitigation, and biodiversity, among others. Systematically monitoring forest regeneration over large and often remote areas of the boreal is challenging. Remote sensing science has long focused on disturbance detection, with capabilities advancing as a result of innovations in data policies, curated data archives, and increased computational capacity. These innovations have enabled disturbance detection at an annual or sub-annual time step, as well as the automated attribution of changes to a causal agent. These same innovations have also enabled the characterization of post-disturbance forest recovery, particularly following stand replacing disturbances.

This capacity to monitor both disturbance and recovery enables a more holistic assessment of forest dynamics. However, forest recovery is a complex process that is highly variable in both space and time. The question of when a forest is considered "recovered" depends on how recovery is defined, which varies according to information need or application, and often confounds assessments and monitoring efforts. For example, a silvicultural definition of forest recovery may primarily relate to the near-term establishment of trees with a certain stocking density, whereas in the context of ecosystem goods and services, recovery may relate to the longer-term restoration of the functional characteristics of forests. As definitions of forest recovery vary, indicators of forest recovery also vary, and may include measures of forest composition, structure, or function. Quantitative indicators of recovery derived from remotely sensed data can support systematic monitoring efforts.

Synergistic use of different remotely sensed data sources is enabling new insights on the nature of forest recovery in the boreal in a manner that is synoptic, spatially-explicit, and spatially detailed. The current and potential future contributions of remote sensing to the characterization of forest recovery in the boreal will be highlighted.

KEYNOTE SPEAKER

How to find sustainable management solutions within a changing climate? – Decision support tools for sustainable forestry.

Karin Öhman

Swedish University of Agricultural Sciences, Sweden

Abstract

The pressure on forest ecosystems is increasing. Forests are now expected to contribute to climate change mitigation by storing carbon and substituting fossil fuels, while also providing beneficial conditions for biodiversity, timber production, recreation, and other important ecosystem services. Conflicts between these aspects have made decision-making for managed forest landscapes increasingly complex. To address this challenge, one key way is through the use of forest planning and future analysis tools.

In my presentation, I will discuss how various decision-support tools can aid forest managers in making more informed decisions about sustainable forest management practices. Projection models that incorporate climate change projections can help us better understand the potential risks and opportunities associated with various management options. Optimization can assist in identifying trade-offs and optimizing our management practices to meet multiple objectives. Data visualization tools can help us observe the spatial and temporal patterns of ecosystem changes. Multi-criteria decision analysis can promote collaboration and communication among stakeholders by ensuring that all stakeholders have a voice in the planning process and that decisions are made transparently and inclusively.

Finally, finding sustainable management solutions within a changing climate is a complex and multifaceted challenge. Decision support tools for forest planning and analysis can help us make informed and sustainable decisions but they must be used in conjunction with other tools and approaches to ensure that forest management is adapted for the necessary climate change transition in a way that does not jeopardize the delivery of important forest values.

INVITED SPEAKER

Synergies among multiple ecosystem services in five European countries.

Silvio Schueler[1], Elena Haeler[1], Jouni Sorvari[2], Thomas Ledermann[1], Robert Jandl[1], Kerstin Westin[3], Torgny Lind[4], Andreas Bolte[5], Ursa Vilhar[6], Mitja Skudnik[6], Raisa Mäkipää[2]

[1]Austrian Research Centre for Forests BFW, Austria. [2]Natural Resources Institute Finland (Luke), Finland. [3]Umeå University, Sweden. [4]Swedish University of Agricultural Sciences, Sweden. [5]Thünen Institute of Forest Ecosystems, Germany. [6]Slovenian Forestry Institute, Slovenia

Abstract

Multifunctional forest management has been the predominant management of European forest providing a multitude of ecosystem services. However, the vulnerability of previous management regimes under the increasing severity of climate-changed induced disturbances and concerns on the future provision of ecosystem services challenge present management strategies. Also, small-scale forest owners, which manage about 50% of European forests face changing societal demands and management constraints and might thus adapt their management objectives and strategies. To quantify the provision of multiple ecosystem services under different management alternatives, we created digital forest twins for Central and Northern European forest ecosystems on basis of national forest inventory data and modeled forest development until the end of the century. The digital twins allow us to quantify a variety of ecosystem services and indicators for biodiversity and to test for trade-offs and synergies among them. Additionally, a survey across forest owners in the same countries allowed us to evaluate the willingness to adapt forest management to climate change and changing societal demands. Our modeling experiment revealed that no single management strategy could be reasonable applied across Europe or even single countries, if a variety of ecosystem services shall be reached. This can be explained by the limited synergies among major ecosystem services such as carbon storage and forest biodiversity indicators. Another limitation for common management strategies is the differing understanding and application of management measures among owners in relation to forest management tradition and value orientation. This indicates a stronger role for regional policies, management strategies and communication in order to consider forest type specific management and country-specific owners characteristics in sustainable forest management.

INVITED SPEAKER

Dealing with natural hazards in decision support

Annika Kangas

Joensuu, Finland

Abstract

Forests are facing numerous natural hazards, and with climate change, we assume that the probability of their occurrence is increasing. We have decision support systems that have been designed to deal with one or more natural hazards, but most forest DSS only cover small-scale mortality due to the tree age and competition.

One important reason why the natural hazards are not included into the systems is a lack of predictive models for the occurrence of the damages and the extent of damages. Partly this lack is due to lack of suitable large-scale modelling data. In addition, many of the existing models require information that is generally not available in the forest DSS.

Another important reason is that all hazards have different nature, and therefore they must be modelled in a different way in the forest DSS. For instance, some of the hazards are such that cause instantaneous damage, some develop for several years or even decades. In some cases, the probability of occurrence can be diminished with pre-emptive actions, or the extent of damage limited with salvage operations. Some of the damages are observable from standing trees, and some can only be detected from felled trees after harvest, some can be simulated on stand level, and some need landscape level analysis.

For long-term scenarios and sustainability assessments, we need better understanding of the effects of such damages. Ignoring the damages may lead to overly optimistic assessment on the potential of our forests for carbon sequestration and storage, as well as for timber production. This presentation gives an overview of possibilities we have in dealing with the various hazards.

INVITED SPEAKER 3.1.1

Soil microbial diversity and functioning of boreal managed peatlands

Petr Baldrian

Institute of Microbiology of the Czech Academy of Sciences, Czech Republic

Abstract

Peatlands store up to one-third of the world's soil carbon as waterlogged conditions slow down organic matter (OM) decomposition. As much as 15 million ha of the temperate and boreal peatland has been drained for forestry in the last century with the aim to produce wood, which have turned soils of peatland forests to sources of greenhouse gas (GHG; CO_2, CH_4 and N_2O) emissions to various extent and depending on their management. The production of GHG in peatland forest soils is largely driven by the activity of their microbiomes – bacteria, archaea and fungi. The microbiology of peatlands is highly complex and has an important spatial component: along peat profile depth, the conditions for microbial life change dramatically since the presence of the water table in soils with high OM content result in the stratification of aerobic, microaerophilic and anaerobic layers. While methane is produced in the anaerobic layers and consumed in the aerobic ones, the production of N2O and its consumption occurs across multiple layers of the peat profile. The understanding of the effects of forest management options, such as clearcutting and continuous cover forestry, is so far incomplete. Yet it is likely that the profound changes that management exerts on GHG emissions are mainly the consequences of the changes in the microbiome structure and function and their interaction with the activity of tree roots. Understanding of microbial processes is needed to decide about the best practices of peatland forestry that minimize the production of GHG and thus the adverse effects on climate.

INVITED SPEAKER 4.1.1

Impacts of future forest use on biodiversity, ecosystem services and climate

Tord Snäll

SLU, Sweden

Abstract

We aim to identify pathways of sustainable future forest management that develops the bio-economy and multifunctional forests by mitigating climate change, delivering non-woody ecosystem services and preserving biodiversity. This will be based on analyses of synergies and trade-offs among alternative uses of forest biomass for Sweden the coming 30 and 80 years. Our methodological approach is to simulate many forest management alternatives for the national forest inventory plots and then apply multi-objective optimization to identify future pathways that fulfil objectives to be specified for the Swedish forest. This optimization will concern harvest level, ecosystem services, biodiversity and climate chance mitigation, the latter based on life-cycle assessment. In the work, we will further utilize models for different non-woody ecosystem services and a wide range of species representing different organism groups. I will present our starting work on joint optimization of objectives on these wide-ranging responses of forest biomass use. In the presentation, I aim to answer these questions: How should we manage and harvest the Swedish forest to make red-listed species increase with 50%, retain current levels of non-woody ecosystem services and obtain maximal climate change mitigation? This will consider both the alternative of storing carbon in the forest or substituting fossil-based products for bio-based products. Will the management be different if the time horizon is year 2050 or 2100? Moreover, can we reach the 50% increase of red-listed species and what will be the effect on climate if we apply BAU forestry and today's protection for conservation versus if we apply forestry according to the EU Biodiversity Strategy (10% strict protection and 20% closer to nature forestry)?

INVITED SPEAKER 4.1.2

Integrated biodiversity conservation and carbon sequestration in the changing environment

Annikki Mäkelä[1], Francesco Minunno[1], Heini Kujala[1], Virpi Junttila[2], Martin Forsius[2]

[1]University of Helsinki, Finland. [2]Finnish Environment Institute (Syke), Finland

Abstract

The EU aims at reaching carbon neutrality by 2050 and Finland by 2035. Boreal forests constitute a large potential sink of carbon which could be an important component in climate change mitigation and adaptation strategies, but simultaneously, enhancing carbon sequestration in forests may have adverse impacts on biodiversity. This presentation summarises findings on the interactions between carbon sequestration and biodiversity conservation in forests, gained in the national research council project IBC-CARBON (https://www.ibccarbon.fi/en-US) in 2018-2023.

To understand how forest management influences wood production, carbon sequestration and biodiversity, we devised different management and protection strategies in interaction with stakeholders. We combined the strategies with different levels of harvest intensity: business as usual, low harvest, intensive harvest and no harvest. The strategies and harvest levels were applied to all forest land in Finland with either current or extended strictly protected areas, following the EU policy of 10% protection in all administrative regions. The extended protected areas were allocated to sites that showed the highest biodiversity value according to Zonation analysis. The resulting management and protection scenarios were incorporated in the forest growth simulator PREBAS. We carried out simulations on a wall-to-wall grid in Finland until 2050 under three climate scenarios. In addition, we studied the uncertainties related to input data, model parameters and scenario definition of both the estimated carbon sequestration variables and the biodiversity values.

In the results, harvest level was key to carbon stocks and fluxes regardless of management actions and proportion of strictly protected forest (current vs extended). In contrast, biodiversity was more dependent on other management variables than harvesting levels, and relatively independent of carbon stocks and fluxes. Net carbon sink showed a declining trend under current climate but had considerable uncertainty, whereas the allocation of sites with high biodiversity values was remarkably robust under input uncertainties.

INVITED SPEAKER 7.1.1

Fine-spatial UAV-albedo in boreal forests

Eirik Næsset Ramtvedt

NMBU, Norway

Abstract

Boreal forest management in the Nordic countries has received more interest from decision makers in the latest years because of the forests' climate mitigation potential. To find effective forest management strategies for global warming mitigation, which is locally dependent, a precise quantification of the shortwave broadband albedo is decisive. During summer and fall 2022, field data, LiDAR data from airborne and UAV platforms, and albedo from UAV (denoted UAV-albedo) were collected for 150 forest plots in a boreal forest in Norway. By this novel collection of albedo data, we aim to improve the knowledge of the interlinkage between different spatial resolutions of albedo and boreal forest structures, as well as validating and developing the knowledge of optical remote sensing data for fine-spatial albedo in boreal forest. Specifically, four topics will be highlighted:

(1) How accurate is accurate enough? UAV-albedo representing different spatial coverage of the measured forest plots will reveal how the spatial resolution of the albedo impacts the relationship with the ground-truth field data.

(2) How suitable is satellite albedo for boreal forests? UAV-albedo compared with different optical satellite albedo products will reveal the suitability of using remote sensing data in heterogeneous forests at stand level.

(3) Does structural information of forest improve albedo estimation based on Sentinel-2 reflectance? UAV-albedo serves as validation when applying two sets of conversion coefficients to estimate Sentinel-2 albedo for structurally heterogeneous forest.

(4) How can UAV-albedo and LiDAR data be exploited for boreal forest management considering climate mitigation in Norway? Tree-specific albedo models will for the first time be implemented in a forest stand simulator parameterized to Norwegian conditions.

INVITED SPEAKER 13.1.1

The PeatPic Community Project: Understanding peatland green leaf phenology using readily-available smartphone photography

Scott J. Davidson

University of Plymouth, United Kingdom. University of Waterloo, Canada

Abstract

Peatlands store one-third of the world's soil carbon and these carbon dynamics are partly driven by understory vegetation such as sedges, mosses, and dwarf shrubs. The phenology of these small-statured plants is difficult to capture with remote sensing proxies. Furthermore, the relationship between leaf phenology and peatland carbon cycling is not fully explored. I leveraged my previous work developing smartphone-based methods for quantifying peatland phenology to initiate a peatland community-based (#PeatTwitter) project called PeatPic. PeatPic provides a platform for smartphone images that can be used to calculate leaf greenness proxies. To date PeatPic has had submissions from 24 sites, with images submitted every 1-2 weeks across the growing season. I will present within- and across-site variation in leaf greenness across a variety of peatland types globally. Future goals include identifying environmental predictors of green leaf phenology and linking phenology to carbon fluxes. I hope to maintain this database as a long-term, adaptable community resource that can improve understanding and modelling of peatland carbon cycling processes

7.2. Sessions

Session 1.1 Peatlands and emissions

1.1.1

Dynamics of CO_2 fluxes measured with the eddy covariance technique 1-7 years after a clear-cut in four forest sites in Finland

Lohila Annalea[1,2], Mika Korkiakoski[1], Olli Peltola[3], Narasinha Shurpali[3], Karri Uotila[3], Helena Rautakoski[1], Olli-Pekka Tikkasalo[3], Raisa Mäkipää[3], Tuula Aalto[1], Hermanni Aaltonen[1], Mika Aurela[1], Aleksi Lehtonen[3], Tiina Markkanen[1], Olli Nevalainen[1], Timo Penttilä[3], Sakari Sarkkola[3], Ahmed Hasan Shahriyer[1], Henriikka Vekuri[1], Tuomas Laurila[1]

[1]Finnish Meteorological Institute, Finland. [2]Institute for atmospheric and Earth system research, University of Helsinki, Finland. [3]Natural resource institute Finland, Finland

Abstract

Forests are the largest carbon (C) sink of terrestrial ecosystems and management has a great impact on their C fluxes. The rate of recovery of the ecosystem C sink after a clear-cut is affected by e.g. the respiration rate of soil organic matter and the logging residues, and the recovery rate of the photosynthesis by green vegetation. Understanding and quantifying these processes is a highly interesting and important question, as direct full-ecosystem measurements at clear-cut sites, encompassing the soil and the vegetation, are still scarce. In this study we show carbon dioxide (CO_2) exchange data from two forestry-drained peatlands and two upland forests 1-7 years after the clear-cut, all located in boreal forests in southern Finland and planted with spruce seedlings soon after the clearcut. We will also compare the CO_2 flux observations to model simulations done by LDNDC ecosystem model. Research questions we want to address are 1) is the recovery rate of net ecosystem exchange and its components, respiration and gross primary production, comparable in different sites and soil types, 2) how well the LDNDC model simulation matches the observations, and 3) which are the drivers for the carbon sink recovery after the clearcut on peatland and upland forests.

1.1.2

Ecosystem-scale observations of CO_2, CH_4 and N_2O fluxes at a drained boreal peatland forest after clear-cutting

Olli Peltola[1], Olli-Pekka Tikkasalo[1], Pavel Alekseychik[1], Samuli Launiainen[1], Aleksi Lehtonen[1], Qian Li[1], Mikko Peltoniemi[1], Janne Rinne[1], Antti J Rissanen[1,2], Sakari Sarkkola[1], Raisa Mäkipää[1]

[1]Natural Resources Institute Finland, Finland. [2]Faculty of Engineering and Natural Sciences, Bio and Circular Economy research group, Tampere University, Finland

Abstract

When drained peatland forests are harvested by clear-cutting, the vegetation and soil biogeochemistry undergo substantial changes due to changes in e.g. soil physical characteristics and microbial activity. These alter ecosystem-atmosphere greenhouse gas (GHG) exchange and increase its spatial variability. Achieving representative estimates of GHG emissions from such an area is a challenging task, but they are sorely needed for developing more climate-friendly and sustainable forestry practices for these ecosystems.

A mature Norway spruce (Picea abies) stand growing on a nutrient-rich drained peat soil was clear-cut in March 2021.The continuous monitoring of ecosystem-atmosphere exchange of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) with eddy covariance (EC) started in Dec 2021. The measurements at the site are part of a larger research effort aimed at understanding climatic impacts of forest management practices on drained peatlands. This study aims at interpreting the spatiotemporal variability of GHG fluxes from the clear cut using the EC measurements gathered during the year 2022.

N_2O emissions showed a distinct annual pattern peaking in late July, but observable emissions were detected throughout the measurement period. On annual scale, the clear cut area was a significant source of CO_2 to the atmosphere (2 kg(CO_2) m-2 yr-1) despite net daytime uptake during late summer. CH_4 emissions were small. The observed GHG fluxes showed wind direction dependency, due to spatial variability of GHG fluxes within the clear cut. To understand this variability, detailed mapping of the clear-cut area was made using drone imaging. The mapping will be combined with EC source area modelling to link the observed EC flux variability to different surface characteristics. Overall, these results provide the much-needed information on the GHG fluxes from drained peatland ecosystems following clear-cut and serve as a baseline when different forest management practices are compared to even-aged forestry.

1.1.3

Peat respiration in drained peatland forests under varying tree harvest regimes

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Abstract

About 15 million ha of peatlands has been drained for forestry to increase the volume of aerobic peat available for tree roots. Simultaneously, the peat that was earlier in anoxic conditions has become available for aerobic decomposers, resulting in increased CO_2 emissions through respiration. To mitigate these CO_2 emissions a proposed solution is to switch from clearcuts to continuous cover forestry targeting to regulate water table (WT) with tree stand evapotranspiration and maintain an optimum WT low enough for tree growth and high enough to protect peat from decomposition. However, it is yet unknown how tree stand volume and site properties interact in controlling WT and peat decomposition.

We aimed at quantifying the effect of tree harvest intensity on WT and heterotrophic peat respiration (R_{HP}) at seven drained peatland forests of varying fertility. We conducted chamber measurements of RHP at plots where autotrophic root respiration was excluded by trenching and the respiration of mosses and fresh litter was excluded by temporarily removing the upmost 5 cm soil layer before the measurements. Seasonal R_{HP} measurements were conducted up to nine years after tree harvesting, with intensities varying from clearcut to different selection harvest regimes and unharvested controls.

Unharvested controls had an average WT depth of about 50 cm, which rose after tree harvesting with the largest increase of 22 cm observed in clearcut sites and a smaller effect found in the selection harvest treatments. The highest R_{HP} rates of 307 mg m2 h-1 were measured at the most nutrient rich site types. Although deeper WT in general increased R_{HP}, tree harvest intensity had only a limited impact on R_{HP}. This suggests that although WT depth of drained peatland forests can be regulated with the tree stand volume, the resulting shallower WT may still be too deep to markedly reduce R_{HP}.

1.1.4

Fine root production in boreal peatland forests: effect of tree species, climate and site nutrient regime

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Abstract

Fine roots are an important component of ecosystem carbon (C) cycling in boreal forests and peatlands. We aimed to estimate fine root production (FRP) for a range of peatland forests and seek for patterns in, and develop models for estimating, the relationships between FRP and above-ground parameters plus environmental and climatic conditions.

We studied FRP of 28 drained boreal peatland forest sites in Finland using ingrowth core method. FRP decreased from south to north along the studied geographic range, but the decrease in FRP with a decrease in long-term mean annual temperature along the climatic gradient was not quite statistically significant. Tree stand basal area predicted FRP (R2m = 0.158, $p < 0.001$) better than any other stand variable alone. FRP varied considerably among the site types, but showed no trend with fertility. A model that included stand basal area and site type accounted for 47% of the variation in stand-level FRP. Most FRP occurred in the top 20 cm layer comprising 76–95% of total FRP. The most fertile site (HrT) showed lower FRP in deeper layers than the other sites. These results help to improve quantification of FRP with forest inventory data.

1.1.5

Implementation and evaluation of Landscape-DNDC model for forestry management methods at a nutrient-rich peatland site in southern Finland.

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Abstract

A process-based model 'Landscape De-Nitrification De-Composition' (LDNDC) was used to simulate fluxes of matter and energy of a drained nutrient-rich peatland forest ecosystem in southern Finland. LDNDC utilizes several sub-models for physiology, bio-geochemistry, hydrology and micro-climate and multiple species can be simulated simultaneously as a mixed forest cohort with contributions of the ground vegetation included. Different management methods of the forestry industry, e.g clear cutting or selection cutting have been simulated successfully.

Local meteorological data from 2010–2018 was used to drive the model and this data was cycled through several times to start the simulation run from 1969. The amount of carbon storage in the soil was set according to the measurements at nutrient-rich peatlands. Three different simulation runs were made for a clear-cut or a selection cutting taking place in 2016 and a reference forest with no cutting. Pine was simulated as a dominant tree species prior to the management actions along with spruce and birch as a secondary canopy and alpine meadows as ground vegetation. Eddy covariance and chamber measurements from both management and reference sites were used to evaluate model performance.

The model captured the net ecosystem exchange, gross primary production, terrestrial ecosystem respiration and methane fluxes well. The model also captured the changes in soil moisture and water-table level caused by the applied forest management methods. Successful implementation of the model resulted in extension of simulations until 2100 using different climate drivers to investigate effects of future management scenarios on various ecosystem balances. These model results can be utilized to provide recommendations for peatland forest management, which can ensure reduction in forestry related emissions and improve the possibilities for the peatland forestry to act as a sink of carbon.

Session 1.2 Multiobjective optimization

1.2.1

Digital twin enabled forest management with multiobjective optimization

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Abstract

While the world is rapidly developing in the digital era, it also must cope with environmental calamities. The most significant is biodiversity loss due to natural area deterioration and climate change. However, biodiversity, natural ecosystems, and the benefits and services provided by these ecosystems are critical elements for social well-being and progress. Therefore, it is essential to protect forests and biodiversity by managing them sustainably within ecosystem integrity to provide multifaceted benefits to society.

To investigate how forest management strategies and climate change scenarios affect forest biodiversity, we create a forest digital twin in predicting forest and biodiversity dynamics and how species interact with their environment and each other. The LANDIS-II forest simulator is used to create virtual representations of Finnish forests, while Hierarchical Modelling of Species Communities (HMSC), a joint species distribution model, is used to create biodiversity models. LANDIS-II simulations under various management options, together with climate change scenarios, predict possible future environmental conditions. HMSC models that relate species dynamics to environmental conditions predict how biodiversity responds to those management options and scenarios. The forest and biodiversity models are united under a forest digital twin to promote sustainable management of the forest's biodiversity and its ecosystems with an acceptable level of accuracy and reliability. To demonstrate the benefits of having the forest digital twin, we propose a digital twin application that utilizes decision support with interactive multiobjective optimization leveraging the flagship EuroHPC LUMI's high-performance computing infrastructure. This approach will support stakeholders in finding the most appropriate forest management strategy considering their preferences as well as the ecological, social, and economic objectives under different climate change scenarios.

1.2.2

MultiForestOpt: simplifying multi-objective optimization for forest planning and scenario analysis

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Abstract

Designing and construction of future scenarios of forest development considering multiple conflicting objectives, restrictions and demands has required specific expertise in forest simulators, optimization, visualization, and stakeholder facilitation. For large scale planning processes, these required expertise can be possible to organize, however smaller processes require easy to use tools that can be understood by various stakeholder groups. MultiOptForest is an open-source software, developed to ease the construction of multi-objective optimization problems for forest planning purposes. In particular, the method used in the software searches for the portfolio of management alternatives that best meets the stated stakeholders demands for multiple forest ecosystem services and biodiversity. The software flexibly imports data, allowing for the use of the best forest simulator available for each specific problem. The software collects preference information from the user through a graphical user interface, where the range of possible values for each objective are provided. The specific construction of the optimization problem requires an advanced understanding of the tool; however, the tool does not require expert understanding of coding or mathematics. The specific multi-objective optimization problem can incorporate multiple conflicting objectives where all only solutions presented to the decision maker are Pareto optimal (any improvement of one objective will result in a deterioration of another objective). The software is flexible enough to allow for assessments of policies that impact the development of forests in multiple European countries. This presentation will demonstrate the software and describe the potential impact for multi-objective forest planning and scenario analyses.

1.2.3

Decision Support for Boreal Forest Planning using Interactive Multiobjective Optimization

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Abstract

Forest planning usually involves large-scale optimization problems with multiple conflicting objectives to be considered simultaneously. Different unit-schedule management options may affect profits, stock levels, and net present value differently. Multiobjective planning involving indicators for carbon sequestration and biodiversity in addition to economic goals is becoming increasingly important. Moreover, the problem of forest management becomes increasingly challenging with a growing number of units and schedule management options.

Current decision-making tools do not adequately help forest planners make informed decisions with multiple objectives. We propose an interactive optimization and decision making approach to iteratively incorporate the preferences of the forest planners. This helps them find management solutions with the best compromise among the objectives. Our decision support tool, DESDEO, helps the forest planners gain insight into the problem. While learning about the interdependencies among objectives and the feasibility of their preferences, forest planners gain confidence in their informed decisions.

We consider a case of boreal forests in Finland with almost 56, 000 units and over 760, 000 unit-schedule combinations generated using the Mela forest simulator. We consider multiple objectives and use efficient techniques to generate a large number of representative compromise solutions. We then use the DESDEO framework, an open-source software for interactive multiobjective optimization, to enable the forest planners navigate the large number of compromise solutions to find the one most preferred by them. The process of generating candidate solutions is time-consuming due to the scale of the problem. Therefore, solution generation beforehand saves the time of the forest planners.

Making better forest management plans implies considering an increasing number of conflicting objectives. With this study, we demonstrate the strengths of interactive multiobjective methods and planning systems in supporting decision makers in considering a very large forest planning case. The support enables comprehending what is achievable and making better informed decisions.

1.2.4

Decision support for sustainable forest harvest planning using multiobjective optimization and the value of information

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Abstract

Digitalization in the forest sector has enabled the collection of large amounts of data, and knowledge of how to exploit the data efficiently is needed. Moreover, handling data uncertainty is crucial in practical data analytics. Usually, we can improve data reliability and prediction accuracy (uncertainty reduction) by gathering more data at some costs. This can be performed by pre-harvest inventories gathering more precise information about the forest stands. A broad spectrum of inventory methods exists in both accuracy and monetary sense, ranging from high-cost and high-accuracy airborne laser scanning to low-cost traditional stand-level methods. Often, more expensive inventory means more accurate data highlighting a trade-off between accuracy and costs. However, the critical question is whether this accuracy improvement is worth the extra costs. This question can be studied by the value of information. Additional support is needed to investigate the value of information and find the best balance between these two conflicting objectives. The primary aim of this study is to investigate the possibility of economic improvement in forest production by increasing data quality in harvest planning, leading to more sustainable forest resource usage. To reach this end, we designed a decision support tool prototype to study the value of information in forest harvest planning utilizing an interactive multiobjective optimization methodology for trade-off analysis.

We examine the prototype's usability with a case study of forest harvest planning in Sweden with 200 stands, three inventory methods, three assortments (pine, spruce, deciduous trees), and a twelve-month harvest planning horizon. Moreover, in this pilot study, we formulate an optimization problem with multiple objective functions, such as minimizing the risk of not fulfilling the demands, minimizing the intervention cost, and maximizing inventory accuracy. We demonstrate how the proposed prototype supports a decision-maker in trade-off analysis and finding the best balance between accuracy and costs.

1.2.5

Optimal forest rotation under carbon pricing and forest damage risk

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Abstract

Forests have two notable economic roles in the future: providing renewable raw material and storing carbon to mitigate climate change. The pricing of forest carbon leads to longer rotation times and consequently larger carbon stocks, but also exposes landowners to a greater risk of forest damage. This paper investigates optimal forest rotation under carbon pricing and forest damage risk. I provide the first-order optimality conditions for this problem and illustrate the setting with numerical calculations representing boreal forests.

Under the considered range of parametrizations, carbon price has far greater impact on the optimal rotation than the damage probability. Increasing forest carbon stocks through longer rotations is thus economically attractive option for mitigating climate change, despite the forest damage risk. Carbon pricing increases land expectation value and reduces the economic risks posed by disturbances. The production possibility frontier between harvests and carbon storage suggests that significantly larger forests carbon stocks are achievable, but implies lower harvests. However, forests' societally optimal role between these two activities is not yet clear-cut; but rests on the future development of relative prices between timber, carbon and other commodities dependent on land-use.

(The presentation is about a paper published in Forest Policy and Economics in 2020, https://doi.org/10.1016/j.forpol.2020.102131)

Session 2.1 Hydrology and its impacts

2.1.1

Restoration of natural hydrology in forests.

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Abstract

This study combines a map study with a field study with the focus on wetland restoration. It investigates three restored wetlands in the forest of Gribskov, Denmark, and whether or not the restoration has been successful in bringing the wetlands back to historical, pre-ditching conditions. The historical conditions are investigated by analysing 19th century maps and by identifying peat in soil samples along transects. The current conditions are investigated through a current forest map and a GIS-based rain fill-model that identifies local depressions in the landscape, as well as measuring ground water depth in the field. The maps used for this study are also held up against each other and compared with the results of the field study to determine how well the delineation fits with the actual measured border of the wetlands. The map study is also done to investigate the timing and intensity of the management actions that have led to the steep decline of wetlands in the whole of Gribskov through time, as well as the opposite trend in recent years. It was found that all three studied cases seem to have been hydrologically well restored, as the correlation between a shallow depth of ground water and presence of peat was high, indicating that the border of the wetland is situated approximately at the same location currently as it did historically. Historical ditching was found to have had a great effect on the decline of wetlands, and modern restoration projects also seem to be an effective measure of bringing the wetlands back. Lastly, the soil samples consistently showed a decrease of peat with increasing distance to blank water and an increase of inorganic mineral soil with increasing distance.

2.1.2

Ecohydrological modelling for boreal forestry

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Abstract

Water is a key resource, a possibility, and the 21st century challenge for boreal forests and forestry. For decades, hydrological research has provided support to the emerging demands for boreal forestry, such as securing the catchment water yield, draining peatlands for wood production, and designing buffer zones for better water quality. The recent diversification in the expectations on forests, accompanied with rapid boreal climate change and acute demand for sound management solutions, now necessitates hydrological research to move from statistical-empirical approaches to wide-spread use of ecohydrological theory and simulation models in decision support.

Boreal forest landscape consists of mosaic of mineral soils and peatlands with varying hydrological characteristics, fertility, species composition and management regimes. The response of boreal forests to climatic trends, variability and extremes (e.g. temperature and precipitation) alone is governed by numerous feedbacks and interactions among the non-linear ecosystem processes. The local water balance, biogeochemistry and forest growth are further modulated by water and nutrient flows through the landscape, and by our management decisions. In this presentation, we demonstrate how ecohydrological theory implemented in process-based simulation models is essential for systemic understanding of boreal forests function and resilience, and how scenario-modeling can lend support to multi-functional forest management decisions from stand to landscape scales.

We review ongoing and recent work in our research team and demonstrate how our simulation models and multi-scale open-source data can, for instance, i) reveal risk hotspots and support mitigating forest drought and heat stress in current and future climates, and ii) quantify how stand characteristics, plant traits and drainage / harvest designs can be used to control peatland water table and its impacts on biogeochemical cycles and productivity.

2.1.3.

Precipitation and beavers contribute to an increase in water color and iron level in boreal lakes

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Abstract

Boreal freshwaters have become browner over the past decades. There is an urgent need for long-term studies to investigate factors driving this brownification process at diverse scales. Here, we studied the long-term changes in the water color of two small boreal lakes during 1994-2018, one lake being used by beavers. We studied the impacts of known browning drivers such as forestry, climate and acid deposition, and investigated a new potential driver, i.e. beaver activity. Iron concentration is often correlated with water color; they were correlated at 0.73 ($P < 0.001$) in our study sites. Thus, we also tested if the above variables impacted iron concentration at our study locations. Our results showed that browning occurred in the beaver lake and 1) beaver floods and precipitation strongly increased the water color ($P < 0.001$, $R2 = 0.70$) but 2) only precipitation drove iron concentration changes ($P = 0.023$, $R2 = 0.351$) although beaver floods almost contributed significantly ($P = 0.053$). In the non-beaver lake 1) water color increased over time due to increased precipitations ($P = 0.006$, $R2 = 0.436$) but 2) none of our studied variables influenced iron concentration. This article shows beaver floods can have strong effects on water color and possibly on iron concentration and may thus override other drivers such as forestry practices and acid deposition. Beavers are important ecological engineers in the boreal environment and substantial perturbators of the riparian area. It is likely that beavers and precipitation have similar effects on hydrological pathways and mobilization of dissolved organic matter and iron from the riparian area. We here present for the first time the addition of beaver floods as a contributing factor to the ongoing browning phenomenon and highlight the importance to consider beavers in future studies on water browning in the boreal region and further.

2.1.4

Short-term effect of thinning on carbon dioxide and water vapour fluxes in a boreal pine forest

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Abstract

The majority of forests in Finland are actively managed for wood production via even-aged forestry (EAF) with 60-100-year rotation period. Thinning is a part of EAF and applied at intermediate stages of the rotation period, aiming to manage between-tree competition and allocate growth-limiting resources to the remaining trees and to increase their growth rate and vitality. Understanding how thinning affects the dynamics of carbon and water cycles is of great importance in order to optimize the role of forests in sustainable climate change mitigation policies for Finland and boreal region at large.

Hyytiälä forest (SMEAR II, FI-Hyy) located in southern Finland was thinned in winter 2020, removing ca. 40% of basal area. We investigated the short-term responses of the moderate thinning on CO_2 and H_2O fluxes using concurrent eddy covariance measurements both above and below the canopy as well as process-based ecosystem model. The thinning turned the forest from a sink to a source of carbon in the first post-thinning year (+89 gCm^{-2}). It then recovered and became a weak carbon sink in the second post-thinning year (-131 gCm^{-2}), which however was still below long-term average pre-thinning carbon sink (-288 gCm^{-2}).

Gross primary production of the ecosystem (GPP_{eco}) decreased by ca. 20% in the first post-thinning year compared to the previous year. This was remarkably smaller than the rate of foliage loss, i.e., ca. 45%, due to increasing photosynthetic efficiency of the remaining trees. The ground vegetation photosynthesis was only a small fraction of GPP_{eco}. Thus, its compensatory effect was rather weak. Total ecosystem respiration showed only marginal difference after the thinning but decreased at stand level and increased at the forest floor. Similarly, the ecosystem level water fluxes were not significantly affected but their partitioning changed: stand transpiration decreased, and at the forest floor, evaporation and transpiration increased.

2.1.5

Soil GHG dynamics after water level rise – impacts of selection harvesting in peatland forests

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Abstract

Managed boreal peatlands are widespread and economically important, but they are a large source of greenhouse gases (GHGs). Peatland GHG emissions are related to soil water-table level (WT), which controls the vertical distribution of aerobic and anaerobic processes and, consequently, sinks and sources of GHGs in soils. On forested peatlands, selection harvesting reduces stand evapotranspiration and it has been suggested that the resulting WT rise decreases soil net emissions, while the tree growth is maintained. We monitored soil concentrations of CO_2, CH_4, N_2O and O_2 by depth down to 80 cm, and CO_2 and CH_4 fluxes from soil in two nutrient-rich Norway spruce dominated peatlands in Southern Finland to examine the responses of soil GHG dynamics to WT rise. Selection harvesting raised WT by 14 cm on both sites, on average, mean WTs of the monitoring period being 73 cm for unharvested control and 59 cm for selection harvest. All soil gas concentrations were associated with proximity to WT. Both CH_4 and CO_2 showed remarkable vertical concentration gradients, with high values in the deepest layer, likely due to slow gas transfer in wet peat. CH_4 was efficiently consumed in peat layers near and above WT where it reached sub-atmospheric concentrations, indicating sustained oxidation of CH_4 from both atmospheric and deeper soil origins also after harvesting. Based on soil gas concentration data, surface peat (top 25/30 cm layer) contributed most to the soil-atmosphere CO2 fluxes and harvesting slightly increased the CO_2 source in deeper soil (below 45/50 cm), which could explain the small CO_2 flux differences between treatments. N_2O production occurred above WT, and it was unaffected by harvesting. Overall, the WT rise obtained with selection harvesting was not sufficient to reduce soil GHG emissions, but additional hydrological regulation would have been needed.

Session 2.2 Habitats and biodiversity

2.2.1

Links between red wood ant (*Formica rufa*-group) mound densities and past/present forest management in Sweden

Emil Andersson

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Abstract

The large mounds of red wood ants (RWA) of the Formica rufa-group are an eye catching sight in boreal forests. RWA are also known to function as a keystone species, as their mounds provide resources and protection for many different arthropod species. The visibility of RWA together with their function for biodiversity make them an ideal target for conservation, but little research and effort has been directed towards this in Sweden. However, it is known that RWA colonies can be negatively affected by logging. Recently international calls have been made for monitoring and protection these ant species.

The Swedish National Forest Inventory (NFI) is a long running project that has been registering RWA mound occurrences since 2003. For the 2021 and 2022 season, we added a collection and specimen identification to the NFI registrations. From the NFI sampling, we found four RWA species, with Formica polyctena and Formica aquilonia occurring more frequently than Formica rufa and Formica lugubris. Being able to correlate RWA mound occurrences with environmental data from the NFI plots allows us to predict what forest variables are important for RWA species. By both looking at the present environment data and the historical record, we can identify the forest management practices and stand development types which benefit wood ants. These links between management and RWA population processes also allow us to make predictions about future RWA populations change, based on modeling how Swedish forests will develop in the future. The goal of these projects is to come up with suggestions for forestry and logging practices that could benefit wood ant conservation.

2.2.2

Improving forest habitat for biodiversity: what influences deadwood amount in European forests?

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IIASA, Austria

Abstract

Deadwood is a key old-growth element in European forests and a cornerstone of biodiversity conservation practices in the region, recognized as an important indicator of forest management sustainability. During the past decades, deadwood availability has been increasing in European forests, however, volumes in managed areas are still far below the amounts occurring in unmanaged forests. Current policy pledges, such as the EU Biodiversity Strategy, aim at improving habitat integrity in Europe, requiring more biodiversity-oriented concepts, including an increase in deadwood amounts. Still, large uncertainties remain on the drivers of deadwood potentials and its spatial distribution in European forests. To fill this gap, we employed the ICP biodiversity survey, providing a comprehensive dataset of deadwood volumes in Europe, with several spatially explicit datasets on climatic and ecological conditions in forest ecosystems. We regressed these predictors against deadwood volumes using a machine learning and a Bayesian hurdle-lognormal model. Our results show that climate and forest attributes are determinant to deadwood availability in European forests, where older and carbon-rich forests in montane areas displayed the highest deadwood potentials. Furthermore, future climate conditions may reduce potential deadwood availability by 8–17%, depending on the scenario considered. Conversely, changes in management towards more biodiversity-oriented concepts can improve potential deadwood availability by 20%. We conclude that forest management may play an important role in safeguarding deadwood in European forests in the future.

2.2.3

Woody debris patterns and processes in a boreal forest can be restored by prescribed burning and variable retention

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Abstract

In Fennoscandian forests, prescribed burning, creation of dead wood, and leaving retention trees are used as restoration treatments. However, their long-term effects on ecosystem processes are not yet well understood.

Our objectives were to analyze the effects of burning, retention level and site conditions on the dynamics of 1) total dead wood volume, 2) distribution of dead wood by size, tree species, mortality mode, decay class and position, 3) bulk density, mass, carbon, nitrogen and other elements' concentrations; as well as cellulose and lignin of bark and wood in the cut down logs.

The inventories were made before, one, 16 and 20 years after restoration treatments within the EVO experiment established in 2001 in mature Norway spruce forests in Southern Finland. The experiment includes partial cuttings with standing retention of 50 m^3 ha-1 with or without prescribed burning and three levels of downed retention (stumps and logs): 5, 30 and 60 m^3 ha-1, as well as controls in both upland and paludified biotopes, with three replicates each.

After 16 years, both volume and diversity of dead wood 1) increased with the level of downed retention, 2) were higher in burnt than in unburnt sites, and 3) were higher in upland than in paludified biotopes. The share of highly decomposed logs was higher in burnt than in unburnt sites, especially in upland biotopes.

The mass loss of cut logs was much faster as compared to earlier reported figures for naturally died trees. The annual decomposition rate of wood varied greatly (from 0.7 to 18.1%) depending on log height above ground and sphagnum cover.

Our findings highlight the long-term importance of prescribed burning, standing and downed retention as nature-based forest management methods for maintaining dead wood diversity and ecosystem functioning.

2.2.4

Combining experimental and temporal observation data to identify species interactions in colonization and extinction of wood-decay fungi

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Abstract

Understanding the distribution and dynamics of species is central to ecology and important for managing biodiversity. Species distribution is determined by dispersal, environmental conditions and interactions between species. For example, fungal species interact within a dead tree log by competing for resources and space, and by decaying the log and facilitating other species. We developed a method that identifies species interactions in temporal presence-absence data by testing how the presence of a predecessor species affects the colonization and extinction of other successor species. We tested our method with temporal data of 12 dead-wood polypore species in 1379 logs inventoried twice in Scandinavia. To further improve identification of species interactions, we supplement the model with data in the form of results from species interaction experiments (informative priors). Environmental conditions (log diameter and decay stage) explained the majority of the variance in colonization dynamics, especially the early-successional species whose colonization probabilities were only affected by log conditions. On the other hand, late-successional fungi were more dependent on interactions with successor species. We identified interactions between 6% of species pairs, and some species had multiple positive or negative interactions with successor species. *Fomitopsis pinicola* had a positive effect on the colonization of two other species, including on *Fuscoporia viticola*, which in turn had a positive effect on two other species. *F. pinicola* presence has previously been shown to have a positive effect on the presence of other species and thus overall log biodiversity. *Trichaptum abietinum* decreased the probability of other species colonizing a log where it was present, and is a competitive early-successional species. This method is novel as it combines temporal presence-absence data and experimental data to estimate how species influence the dynamics of others. Such knowledge is important in developing management methods to maintain biodiversity.

2.2.5

Changed species colonization-extinction dynamics in plant communities given changed forest and climate conditions.

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Abstract

Modifications of forest ecosystems due to global change, conjointly with forest harvesting, are shaping long-term transformations of boreal forest biodiversity. These drivers are modifying the structure and composition of the stand forest that determines the composition and dynamics of the understory plant communities. In order to study large-scale and long-term changes in understory plant communities, we take into account the dynamics of individual species, i.e. colonization and extinction rates. In this sense, our aim is to test and estimate size of the effects of stand structure conditions, forest management actions and climate on the dynamics of understory plant communities. We used hierarchical species community models to analyze changes in the rates of colonization and extinction of plant species depending on stand structure and climate conditions. For this purpose, we used vegetation-monitoring data from permanent plots in the Swedish National Forest Inventory from 1993 to 2021. In order to analyze the functional diversity responses, we integrated functional traits of the species. Finally, to study the interactions between species in understory plant communities, we investigated the effects of species presence and cover on colonization-extinction rates. We expect changes in colonization and extinction according to the species and its associated functional traits, and thus modifications of understory plant communities, depending on the stand structure and climatic conditions. Plant species favored by increased light would have a higher colonization rate, or lower extinction rate, in young, less dense stands. On the contrary, shade-favored plant species will have a higher colonization rate when forest stands become denser. We expect cascading effect of forest management, through the modification of stand structure, on colonization and extinction rates of plant species. We therefore expect changes in the structure of the understory plant community after canopy opening by forest management but also by ground disturbance.

Special session 3.1 Functioning and sustainable management of boreal peatland forests

3.1.2

The effect of two different cutting methods on net CO_2 exchange in a nutrient-rich peatland forest

Mika Korkiakoski[1], Paavo Ojanen[2], Juha-Pekka Tuovinen[1], Kari Minkkinen[2], Olli Nevalainen[1], Timo Penttilä[3], Mika Aurela[1], Tuomas Laurila[1], Annalea Lohila[1]

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Abstract

Wide-spread harvesting of forests growing on drained peatlands is foreseen to take place in Finland in the near future. A hot question is if continuous cover forestry utilizing partial cuttings could be used to mitigate carbon dioxide (CO_2) emissions and the consequent climatic impact compared to traditional clear-cutting and even-aged forest management.

To assess the impact of clear-cutting vs. partial cutting, we first measured CO_2 exchange with the eddy covariance method for six years in a mature, nutrient-rich peatland forest in southern Finland. Part of the forest was then partially cut (70% of the basal area), and part of it was clear-cut, and CO_2 exchange of both areas was measured for another six years. Tree growth was recorded before and after the cuttings to separate the contributions of tree stand and forest floor to CO_2 exchange.

Before the cuttings, the annual CO_2 exchange was close to zero, but both cutting methods turned it into a CO_2 source. The partial cutting area became a CO_2 source for the first three years but turned into a CO_2 sink after that, while the clear-cut area was a large, although diminishing, CO_2 source for the whole measurement period. The total six-year CO_2 balances before and after partial cutting did not differ significantly, while the emissions after clear-cutting were on average 2240 g CO_2 m^{-2} yr^{-1} larger than before it. The forest floor was losing carbon both before and after the cuttings. In conclusion, partial cutting resulted in clearly smaller CO_2 emissions than clear-cutting at least in the short term. However, because trees form only a temporary carbon storage in commercial peatland forests, maintaining the peat carbon storage is the key to mitigate climatic impact in the long-term, which cannot be tackled by changing only the cutting method.

3.1.3

Peatland forest CO_2 fluxes and their controls: Does continuous cover forestry help to reduce soil emissions?

Helena Rautakoski[1], Henriikka Vekuri[1], Kristiina Koivu[1], Mika Korkiakoski[1], Markku Koskinen[2], Päivi Mäkiranta[3], Mikko Peltoniemi[3], Aleksi Lehtonen[3], Raija Laiho[3], Raisa Mäkipää[3], Paavo Ojanen[3,2], Annalea Lohila[1,2], Mika Aurela[1]

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Abstract

Greenhouse gas emissions of drained peatlands have received attention in recent years as countries aim to minimize land-use emissions as part of their climate change mitigation actions. In Finland, drained peatland forests are actively used for forestry and there's pressure to reduce peatland forest soil emissions while still being able to use the wood. Continuous cover forestry has been suggested as one solution, although the wish for climate benefits largely relies on hypothesis.

We tackle this question of the impact of continuous cover forestry on the carbon dioxide (CO_2) emissions of drained peatland forest soils by using recent eddy covariance and automatic chamber data measured in a nutrient-rich peatland forest site Ränskälänkorpi in Southern Finland. Year-round CO_2 flux data before and after selection harvest is examined to see if harvesting has resulted in changes in the net CO_2 balance of the forest or affected CO_2 exchange at the forest floor. Heterotrophic respiration data is used to find controls of peat decomposition and to evaluate the impact of changing groundwater table level on soil CO_2 emissions.

The results provide understanding of peatland forest CO_2 flux dynamics, showing how CO_2 fluxes on the ecosystem scale and on the forest floor, are controlled by environmental conditions and affected by selective harvesting. Therefore, the results contribute to the understanding needed to reduce emissions from drained peatlands.

3.1.4

Mosses as biofilters for ditch methane emissions from forestry drained peatlands

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Abstract

Ditches of forestry-drained peatlands are an important source of methane (CH_4) to the atmosphere. These emissions are currently estimated using the IPCC Tier 1 emission factor (21.7 g CH_4 m^{-2} y^{-1}), which is based on limited number (11) of observations and does not take into account that the emissions are affected by the condition, such as the extent and type of plant cover, and age of the ditches. To construct more advanced ditch CH_4 emission factors for boreal peatlands in Finland, we analyzed ditch CH_4 emissions in 21 study areas. Furthermore, the underlying CH_4 cycling processes were studied in one nutrient-rich peatland site by analyzing $\delta^{13}C$ of CH_4, CO_2 and *Sphagnum* mosses. The mean yearly CH_4 emissions (±standard error) were 2.6±0.8 g CH_4 m^{-2} y^{-1} and 20.6±7.0 g CH_4 m^{-2} y^{-1} in moss-covered and moss free ditches, respectively. Hence, Tier 1 emission factor overestimates ditch CH_4 emissions through dramatic overestimation of the emissions of moss-covered ditches, irrespective of whether they harbor potentially CH_4 conducing vascular plants. Moss-dominated ditches were occasionally even net sinks of atmospheric CH_4. These results can be explained by active CH_4 consuming microbes inhabiting surface water and moss layer. Isotopic mass balance calculations indicated that 10–28% of carbon in ditch *Sphagnum* mosses potentially originated from oxidized CH_4. Ditch network maintenance, including removing mosses, is likely to decrease along with changing peatland forest management, e.g., avoidance of clear-cuttings and shift to continuous cover forestry. Our results suggest that ditches overgrown by mosses have potential to reduce CH_4 emissions from drained peatland forests and could serve as an additional greenhouse gas mitigation measure to management practices that maintain a continuous forest cover, attenuate the changes in water table level and thus reduce CH_4 emissions from peat soils.

3.1.5

Regeneration of drained boreal Norway spruce peatland sites after selection harvesting targeting to continuous cover forest management (CCF)

Sakari Sarkkola[1], Mikko Kuronen[1], Hannu Hökkä[1], Mari Myllymäki[2], Mikko Peltoniemi[1], Raisa Mäkipää[1], Markku Saarinen[1]

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Abstract

It has been suggested that continuous cover forestry (CCF) is a feasible alternative to decrease the negative impacts of traditional even-aged management on carbon and water emissions from drained nutrient-rich spruce peatland forests. CCF relies on maintaining significant tree stand transpiration and interception capacity to control the water table in all phases of management. However, important prerequisite for the sustainability of the CCF is that the forests regenerate sufficiently after selection harvesting. The study aim was to elucidate the factors controlling the regeneration dynamics and performance of Norway spruce seedlings in selection harvested nutrient-rich drained peatland sites. The study material was collected from five experimental sites in Southern and Northern Finland. Each site had 4–15 sample plots (ca 2000 m^2) which included unmanaged controls and light (post-harvest basal area BA 17 m^2) and heavy (post-harvest BA 12 m^2) harvest treatments. Seedlings and soil surface properties were inventoried using systematical grid of small seedling plots (4 m^2) both before harvesting and four growing seasons after treatment. Factors controlling the number of seedlings and their post-harvest change was statistically tested using mixed model approach.

On average, 9300–20600 spruce seedlings/ha were found in the fourth year since harvesting, mostly in heavily treated stands in N-Finland, although the differences among treatments were non-significant due to large intra- and inter-plot variation. About 2/3 of the seedlings had established before harvesting and according to modelling results, the post-harvest regeneration was mostly controlled by the coverage of the bare slash and litter surfaces on the soil. On average, 31% of the sample plots were empty. Overall, spruce peatlands had high regeneration potential, and although the spatial variation is large and only part of the seedlings grow into larger trees. However, more information on the long-term growth and performance of the seedlings across successive harvestings is needed.

Session 3.2 Forest monitoring systems

3.2.1

Quantifying the value of using detailed forest inventory information in a Norwegian context

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Abstract

Errors in inventory data used for forest planning could lead to sub-optimal management decisions and high economic losses. Usually, in forestry, inventory approaches are assessed based on the level of accuracy and precision. However, this does not allow to analyze the usefulness of the data for decision-making purposes. Evaluation of the value of information (VoI) allows to assess the usefulness of the data obtained with different inventory approaches for specific decision-making problems.

This presentation will explore differences in the value of information obtained from four forest inventory approaches that rely on airborne laser scanning (ALS): mean stand values area-based approach (ABA-MV), diameter distribution area-based approach (ABA-DD), individual tree crown (ITC) segmentation and semi-individual tree crown (SITC) segmentation. ABA-MV is the most widely used inventory approach in Norway, however, it could potentially be highly misleading, due to inappropriate diameter distribution model used for growth and development simulations. Therefore, to provide quantitative information on why alternative inventory methods are better, we calculated the VoI for specific decision-making problems. This was accomplished through the application of stochastic programming incorporating uncertainty in tree-level data obtained with all four inventory approaches. The developed stochastic programming model aims to maximize net present value, while minimizing conditional value at risk (CVaR) of not achieving periodic income targets. We explore the difference in stochastic model solutions based on different income targets and different levels of risk aversion preferences of the decision-maker. CVaR proved to be an effective tool to ensure incomes even-flow. The results of the study demonstrate when higher-quality data from improved inventory methods should be used in forest planning, and when less accurate data may be preferred in other specific cases.

3.2.2

Data assimilation for forest inventory: first Norwegian experiences

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Abstract

The data assimilation (DA) technique has been efficiently used for many decades in meteorology and robotics for predicting the state of a system that evolves in time by combining model-based forecasting with repeated observations. It has recently been studied in connection with forest inventory applications by the Swedish University of Agricultural Sciences. Within the SmartForest project, we further investigate the usefulness of the DA techniques for forest inventory and management. Our first study area is located in Våler municipality, Norway. We use growing stock volume as our target variable, which is predicted across a 20-year period based on repeated acquisitions of remotely sensed (RS) data.

The RS data are airborne laser scanning (ALS) point clouds, digital aerial photogrammetric point clouds, and Landsat spectral data. The RS data are available from 1999 to 2022. Data from three field campaigns are available as reference data in our analysis. In between the campaigns, we used a forest simulator to update the reference data for each year. The DA technique employed the use of model-based predictions of growing stock volume from the RS data and took into account that prediction errors tend to be correlated. We used generalized additive models as a modeling technique, allowing us to obtain accurate predictions. We also integrated calibration models into the DA procedure, thereby improving the efficiency of the DA procedure. Our results show the potential of DA to enhance the accuracy of predictions and potentially minimize the costs of field data collection.

3.2.3

The Forest Observation System – a global harmonised in-situ data repository for forest biomass maps validation

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Abstract

Monitoring of forest biomass and biomass change is needed as essential climate and ecosystem variables. New innovative space instruments especially designed for the task have been launched recently and more are expected in the near future. These space-based instruments require ground-based estimates for algorithm calibration and product validation. The Forest Observation System – FOS (http://forestobservation-system.net/) is an international cooperation to maintain a global in-situ forest biomass database to support earth observation and to encourage investment in relevant field-based observations and science. FOS aims to link the Remote Sensing (RS) community with ecological and forest inventory teams working on the ground for a common benefit. The benefit of FOS for the RS community is the partnering of the most established ecological research teams and networks that manage permanent forest plots; to overcome data sharing issues and introduce a standard biomass data flow from tree level measurement to the plot level aggregation. Ecologists benefit from the FOS with improved access to global biomass information, data collecting protocols, gap identification and potential improved funding opportunities to address the known gaps and deficiencies in the data. FOS is an open initiative with other networks and teams most welcome to join. The online database provides open access for plots where the authors have granted access. A minimum set of database values includes: plot coordinates, canopy height and above ground biomass of trees. Plot size is 0.25 ha or large. Large plots are divided by sub-plots in order to observe the variability in height and biomass. The database is essential for validating and calibrating satellite observations and various models. Comparison of plot biomass data with available global and regional maps (incl. GlobBiomass, CCI Biomass, NASA JPL, ICESat-2) shows wide range of uncertainties associated with biomass estimation.

This study is supported by the European Space Agency.

3.2.4

Age-dependent stand biomass models based on the Finnish National Forest Inventory data

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Abstract

To harness the climate change mitigation potential of boreal forests, information on carbon stocks and the rate of carbon accumulation in different environmental conditions is needed. While previous studies show general patterns and mechanisms for age-dependence of stand biomass, simple stand-level models that address the age-biomass relationship on average in managed boreal forests in different environmental conditions are largely missing. We present models for the relationship between stand age and biomass by forest types on peatlands and mineral soils across climate zones in managed forests in Finland based on National Forest Inventory measurements from 1996 to 2018. We also show at which rate biomass accumulates in different growth conditions. The novelty of these models is that they are based on data covering multiple realizations of past management and representing decisions of different forest owners. In northern Finland the maximum biomass change rate was one third, and the maximum biomass stock less than half of the corresponding values in sub-xeric heath forests on minerals soils in southern Finland. On drained peatlands the maximum biomass growth rate was approximately half, and on undrained peatlands one third of the maximum growth rate on mineral soils. On most fertile sites on mineral soils the maximum biomasses were three times larger than on the poorest sites. Correspondingly, the maximum biomass stock change rates were almost eight times faster on most fertile sites. In the example cases, the highest annual biomass change rates were achieved in young forests on average at the stand ages of 7–32 years, whereas the 95% of the maximum stock were reached on average in stands of 63–147 years. The developed models can be used in decision support tools for mapping carbon or creating simple predictions of biomass stock development in regions, or estimating the magnitude of carbon offsets projects.

Special session 4.1 Managing for diversity I: A call for a better understanding of linkages between forest structure, biodiversity and carbon cycle

4.1.4

Biodiversity and climate synergies in managed boreal forests achieved by protecting carbon storages, not sinks

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Abstract

Forests play a central role in the global efforts of halting biodiversity loss and mitigating climate change. In Finland, they harbor significant proportion of our nationally threatened biodiversity and act as major carbon sink that balances the national carbon budget. Both forest biodiversity and carbon services are reduced by large scale harvesting of wood. Preventing harvests through forest conservation can therefore have synergistic benefits, and the idea of including areas of important carbon services into protected area designation has been increasingly advocated. Here we explore how well biodiversity and carbon values co-occur in the Finnish forests and what trade-offs might emerge if the emphasis of carbon services is increased in the designation of future protected areas. We used spatially explicit models to estimate carbon and biodiversity values in forest across Finland and created alternative scenarios to meet the EU's 30% protection target, varying the emphasis given to carbon over biodiversity. We found that whereas forests with large carbon storages often also harbor important biodiversity values, there was little to no correlation between forests with largest carbon sinks and biodiversity. The amount of carbon stored and sequestrated by additional protected areas can be increased to a degree but selecting new protected areas purely based on their carbon values produces highly sub-optimal solution for biodiversity. Our results highlight the importance of carefully exploring the trade-offs between biodiversity conservation and climate mitigation and the need to clarify the meaning and role of carbon storages vs sinks when discussing these partly synergistic objectives.

Session 4.2 Economic and societal perspectives

4.2.2

Substitution and carbon storage impacts of harvested wood products - Effects of increased cascading with different market responses

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Abstract

The avoided emissions by wood use can be measured by substitution impacts and changes in product carbon stocks. Cascade use of wood can further help to avoid emissions by increasing resource efficiency and aiming to minimize the impact on the climate by decreasing for example harvest pressure. However, this is not always the immediate effect and cascading may have indirect market effects that change the production dynamics, thus cause changes in the product portfolios. This study analyses the impact of wood cascading on the climate under varying market responses. Cascade use here refers to discarded sawnwood product utilisation in material production. The study utilises explorative scenarios where Finnish waste wood streams are shifted from current energy use to material use. The scenarios portray plausible market responses to cascading, with cascade production either leading to additional wood-based panel and composite production, or substituting primary sawnwood products thus leading to lower overall wood use (less virgin wood required). The preliminary results show that the cascading can result in 1.6%-5.4% more avoided C emissions compared to reference when considering the substitution impacts, the carbon stock changes in wood products, and the avoided carbon loss from roundwood harvest. Besides the market response, the results vary depending on the time period selected for the estimation of the average annual carbon stock change of wood products and the emission profile of non-wood products. There are less avoided C emission gains in the technosystem, if cascading production substitutes primary production and therefore reduces the wood harvest. However, the opposite holds, if the average substitution impacts are significantly reduced in the future due to decarbonization of non-wood sectors. Thus, in the long-term, extending the overall product lifetimes or increasing net sinks in the forest ecosystem may provide more climate benefits than substitution.

4.2.3

EU Forest Area Protection: Reduced Harvest Potential and Unintended Displacement Effects

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Abstract

The goal of the EU Biodiversity Strategy for 2030 is to protect 30% of EU land and sea areas by 2030. This would reduce EU harvest potential by 5-20% (50-200 Mm3/yr) depending on how the protection target is implemented and allocated over the EU forest area. In this study, we analyze the displacement effects of the protection target on other world regions, other land-use sectors, and the remaining unprotected forest area. The analysis is based on the global spatially explicit forest sector model (GLOBIOM-forest), which is extended to include age-class dynamics. Our results indicate that looking at the harvest potential reduction alone might be misleading and can result in an overestimation of the impact of the protection target on the EU forest sector. There are several reasons for this. First, additional protected areas are not necessary in full production use, which means that the reduction of harvest potential due to protection is not directly reflected in the realized harvests. Second, the impacts of the protection target can be outsourced to other regions or sectors. Third, the impacts of the protection target can be compensated partly by intensifying management in the remaining EU forest areas. The last observation also provides some new insight into the old land-use debate between land-sparing and land-sharing. According to our results land-sparing, i.e., strict protection combined to intensive management would help to maintain the EU forest carbon sink in the short-run while land-sharing, i.e., extensive management would be better solution for the carbon sink in the long-run.

4.2.4

CO_2 removal technologies and the optimal role of global forests in a welfare-maximizing climate policy

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Abstract

The optimal role of global forests in a welfare-maximizing climate policy depends on the availability of CDR technologies. Forest can remove carbon by sequestering it into vegetation and soils or by providing wood for use with Carbon Capture and Storage (CCS). Carbon can also be removed by other means that do not involve forests. Direct Air Capture and Storage (DACS) represents such an outside option. Optimal forest use depends on the outside option's costs and scalability. Due to the large climatic impacts of harvests, the social cost of wood use with CCS is high – even higher than that of DACS (which is a highly energy-intensive technology). Hence, if cheaper outside options for CDR exist, forests are optimally used for sequestration rather than harvests. Extensive wood use with CCS is only optimal if there are no cheaper options. Wood use without CCS is not optimal if CCS is available. The analysis is conducted using ICICLE, a new stylized intertemporal integrated assessment model comprising the global economy, forests, and the climate system. The availability of CDR technologies strongly affect the global forest carbon sink during 2020-2100. Estimates of its size range from -77 to +115 PgC in alternative scenarios. Climatic and economic factors cause differences in the social profitability of wood use across biomes. The presentation reflects on how and why the circumstances in boreal forests differ from the temperate and tropical forests.

4.2.5

Importance of ownership type on forest management

Endre Hofstad Hansen, Hanne Sjølie

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Abstract

In many countries, forests are owned by several owner types, like the state, local authorities, non-industrial private and industry. The knowledge of private, non-industrial forest owners' attitudes and forest management behavior is ample. However, companies, being private or public, have different modus operandi than the diverse group of non-industrial owners. Companies are steered by the owners through boards which sets economic return requirements and run by professional owners. Supposedly, non-economic versus economic objectives may for this group differ from many non-industrial owners that are known to manage according to a broad set of objectives. Better understanding of consequences of ownership type is relevant in the current debate of sustainable forest management and design of policy instruments. However, there is hardly any systematic documentation of the importance of ownership type on forest management. We aim to fill part of this void by comparing key stand-level and harvest attributes across owner types using eastern Norway as a case study. To do this, we use satellite data of forest volumes and age as well as recent changes in forest cover. We combine these data with property data from public land register and data of infrastructure and terrain properties. Through statistical analyses we unveil if there are differences in ownership types, and along which lines these differences are seen. This insight is important for policymakers and bureaucrats that are designing policy instruments to ensure that forest is subject to sustainable management across all ownership types.

4.2.6

Carbon dynamics modeling for woody biomass recovered from wildfire fuel management to the bioeconomy

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Abstract

Wildfires in British Columbia, Canada, driven by a legacy of wildfire suppression and a warming climate, have become one of the dominant sources of greenhouse gas emissions. Fuel management activities — such as salvage logging, thinning, and slash pile removal — help reduce fire risks on the landscape, while recovering woody biomass for the bioeconomy. Efficient uses, such as construction, novel bioproducts, and bioenergy, may further contribute to climate change mitigation through carbon storage and substitution. However, these fuel reduction activities may fundamentally change the type of fiber that can be transferred to the industry.

Existing wood flow and carbon dynamics modeling has relied on conventional harvesting and industry production data, but woody biomass recovered from fuel reduction activities is unlikely to yield the same species, sizes, and quality as a commercial clearcut.

To understand the impact of these changes, we developed a prototype model to estimate the quality and size composition of the recovered woody biomass using species, age, spatial information (site index, biogeoclimatic zone, and timber supply area) and corresponding yield curves. We then allocated the biogenic carbon to the appropriate processing facilities based on the composition to simulate future carbon emissions, with consideration of hypothetical bioeconomy policy and market conditions.

Session 5.1 Managing for diversity II: A call for a better understanding of linkages between forest structure, biodiversity and carbon cycle

5.1.1

Ecosystem-based management as a reference for sustainable forestry in Fennoscandia

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Abstract

A large proportion of the forest land in Fennoscandia is managed for timber production. At the same time various environmental measures are implemented in forestry to improve conditions for biodiversity and ecosystem functions. The question is if this is adequate to ensure sustainable forestry according to the principles of ecosystem-based management (EBM)? We have collated 9 generic conditions from selected international policy documents and compared these to the reality in forests in Fennoscandia as reflected in the scientific literature. These conditions specify how EBM should preserve or improve natural ecosystem structure, functions and ecosystem services, their connectivity and resilience, as well as ensure adequate protection. They also emphasize that management should consider the natural spatio-temporal variability of ecosystems, possible effects on non-target ecosystems, and take a long-term and precautionary perspective. The strong emphasis on supply of timber has ensured long-term sustainability of the timber resource under current environmental conditions. However, inadequate environmental measures and low levels of forest protection have failed to maintain or improve many essential habitat elements for a wide range of native forest species, have reduced many ecosystem functions as well as ecosystem services other than production of timber and game meat, resulting in a deteriorated ecosystem condition. Relatively short harvest cycles and even-aged forest management have drastically shortened turnover times and created landscape patterns of tree age classes that deviate strongly from those found in forests under natural dynamics. The likely effects on forest ecosystem of climate change within the next forest generation seem to be little concern in current forest management. Overall, forest management in Fennoscandia seems to deviate considerably from the EBM paradigm and to fit better with a paradigm suited to industrial agriculture. We provide recommendations for Fennoscandian forestry that aim to improve its sustainability and alignment with the principles of EBM.

5.1.2

How do functional traits, species properties and climate influence tree mortality across Europe?

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Abstract

Tree mortality occurs sporadically due to disturbances and continuously as background mortality that is largely driven by inter-tree competition. Both mortality types are increasing in Europe, partially because of climate change that alters disturbance regimes and increases competition by increasing stand densities.

We used forest inventory data to study how functional traits, species properties and climate influence tree mortality probabilities across Europe. We used Bayesian inference to model disturbance mortality and a frequentist approach to model competition-induced mortality.

The probability of disturbance mortality varied depending on tree characteristics and disturbance agent. For example, increasing tree size decreased sensitivity to fire, but increased sensitivity to wind. Species with a high height to DBH ratio, low wood density and low root depth were sensitive to storms, while species with thick leaves, low wood density and low stomatal conductance were sensitive to fire. In the analysis of background mortality, competition had a higher contribution to tree mortality probability compared to drought events and climate. Increasing stand densities increased the probability of competition-induced tree mortality in both monospecific and mixed stands, but with a different magnitude depending on stand composition and tree species shade tolerance.

Our findings increase understanding on tree mortality. This understanding is necessary in forecasting how changing climate, stand structures and disturbance regimes will impact tree mortality and forest dynamics in the future.

5.1.3

Forest structure and naturalness in the Finnish national forest inventory

Mari Myllymäki, Tuominen Sakari, Mikko Kuronen, Packalen Petteri, Kangas Annika

Natural Resources Institute Finland (Luke), Finland

Abstract

There is great interest to identify and locate natural forests as accurately as possible, because they are considered to have a key role in the prevention of biodiversity loss. Natural forests in boreal region are described to have considerable amount of dead trees and coarse woody debris, large variation in tree age, tree size and species composition, occurrence of trees from previous generations and stable microclimate. Nevertheless, an unambiguous definition of these forests is still missing in the Finnish national forest inventory (NFI). Therefore, we investigated the value of metrics defined based on tally tree locations and sizes only in characterizing a key aspect of naturalness, namely structural naturalness as defined in the Finnish NFI. We used different metrics to quantify variations in tree sizes at plot level, and we summarized the spatial pattern of trees by a spatial aggregation index. We compared the metrics and species proportions in the three classes of structural naturalness, 'natural', 'near-natural' and 'non-natural', evaluated in the field based on non-numerical guidelines. We also used the metrics to predict structural naturalness using the random forest algorithm. We found out that the forests evaluated as structurally natural forests in the field had higher variations in tree size and species composition and more clustered pattern of trees on average, but all studied metrics had high variation in the different levels of naturalness. Consequently, based on these metrics and random forest algorithm, it was possible to have high precision in the classification only if accepting simultaneously low recall, and vice versa. Thus, the link between the inspected structural indices based on the tree locations and sizes and the structural naturalness evaluated in the field in the Finnish NFI was only weak. Using additionally information about the age of forest led to better classification results.

5.1.4

The carbon balance of boreal old-growth forests in relation to lichen diversity

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Abstract

The fragmentation of boreal forest landscapes due to intensive management has caused both a severe decline of biodiversity and significantly altered their carbon dynamics. Old-growth forests are substantial carbon storages and function as habitats for a wide range of boreal forest species. Epiphytic lichen diversity is dependent on forests with large old trees and acts as an effective indicator of overall forest biodiversity. The carbon sink capacity of old-growth forests is currently insufficiently known due to lack of repeated measurements. Moreover, the links between lichen conservation and forest carbon storage are, to date, unexplored. We examined the carbon dynamics of boreal old-growth forests based on a repeated inventory dataset. It consisted of measurements from 1990 to 2019 from 27 unmanaged Finnish coniferous-dominated forest stands. We also investigated whether the occurrence of red-listed epiphytic lichens coincides with high carbon storage based on a species inventory conducted from 2020 to 2021 at the same sites. The estimated volume of standing trees and dead wood, and the carbon content of topsoil were higher than in managed forests. Estimates of NPP increased during the measurement period indicating an increasing trend of carbon sequestration. However, the standing volume remained stable because a large proportion of the biomass increment was allocated to dead wood. The study revealed variable relationships between lichen diversity and forest structure. The species richness of red-listed lichens and stand biomass had a marginally significant positive relationship. The species richness of red-listed lichens increased with stand age, canopy cover, and the relative basal area of deciduous trees, but none of these relationships were statistically significant. However, a statistically significant positive relationship was found between the number of red-listed lichen occurrences and stand age. Our results confirm that preserving the characteristics of boreal old-growth forests benefits both climate change mitigation and biodiversity conservation.

5.1.5

Future wood demands and ecosystem services trade-offs: A policy analysis in Norway

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Abstract

To mitigate climate change, several European countries have launched policies to promote the development of a renewable resource-based bioeconomy. These bioeconomy strategies plan to use renewable biological resources, which will increase timber and biomass demands and will potentially conflict with multiple other ecosystem services provided by forests. In addition, these forest ecosystem services (FES) are also influenced by other, different, policy strategies, causing a potential mismatch in proposed management solutions for achieving the different policy goals. We evaluated how Norwegian forests can meet the projected wood and biomass demands from the international market for achieving mitigation targets and at the same time meet nationally determined targets for other FES. Using data from the Norwegian national forest inventory (NFI) we simulated the development of Norwegian forests under different management regimes and defined different forest policy scenarios, according to the most relevant forest policies in Norway: national forest policy (NFS), biodiversity policy (BIOS), and bioeconomy policy (BIES). Finally, through multi-objective optimization, we identified the combination of management regimes matching best with each policy scenario. The results for all scenarios indicated that Norway will be able to satisfy wood demands of up to 17 million m^3 in 2093. However, the policy objectives for FES under each scenario caused substantial differences in terms of the management regimes selected. We observed that BIES and NFS resulted in very similar forest management programs in Norway, with a dominance of extensive management regimes. In BIOS there was an increase of set aside areas and continuous cover forestry, which made it more compatible with biodiversity indicators. We also found multiple synergies and trade-offs between the FES, likely influenced by the definition of the policy targets at the national scale

5.1.6.

Enhancing resilience of boreal forests through management under global change: A review

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Abstract

Boreal forests provide a wide range of ecosystem services that are important to society. The boreal biome is experiencing the highest rates of warming on the planet and increasing demand for forest products. Climate change and its associated extreme events (e.g., windstorms) put at risk the capacity of these forests to continue providing ecosystem services. Thus,enhancing forest resilience recently gained a lot of interest from theoretical perspective. Yet, it remains unclear how to translate the theoretical knowledge into practice and how to operationalize boreal forest management to maintain forest ecosystem services and functions under changing global conditions. In this study, we review the concept of resilience in forest sciences, how extreme events may put boreal forests at risk, and how management can alleviate such risks or make them more severe. We identify and summarize the main management approaches (natural disturbance emulation, landscape functional zoning, functional complex network, and climate-smart forestry) that can promote forest resilience. We further analyze the role of forest management to increase forest resilience to the combined effects of climate change and extreme events. We found that the combined effects of increased temperatures and extreme events are having negative impacts on forests. Then, we discuss how the main management approaches could enhance forest resilience and multifunctionality (simultaneous provision of high levels of multiple ecosystem services and species habitats). Finally, we identify the complementary strengths of individual approaches and report challenges and opportunities on how to implement them in practice.

Session 5.2 Perceptions and acceptance

5.2.1

Perceptions of forest professionals on managing forest disturbance to enhance forest resilience

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Abstract

Climate change is altering the operational environment of forest management. The need to increase forest resilience and manage forests based on the best available science is urgent. However, it is unclear to what extent scientific evidence on the topic is taken up by forest experts and transferred into practical forest management guidance. To explore how the science-practice interphase works in forest management guidance, we reviewed literature on the effects of forest management measures on disturbance impacts and conducted two rounds of interviews: first we interviewed forest professionals from nine European countries on how they suggest to best increase resilience to forest disturbances, and second we interviewed forest professionals responsible for developing and adapting forest management guidelines in five European countries on how forest management guidelines as an integral part of the science-practice interphase contribute to this process. We found that forest professionals are taking actions to increase forest resilience but there is a divide between the forest management measures studied by the literature and proposed by the forest professionals with some measures being promoted with little or contrasting evidence, indicating that the science-practice interphase is only marginally functioning. The lack of salient information that would facilitate the practical application and the lack of financial and professional capacity were seen as the main challenges in adapting forest management. The results showed that there is a need to enhance the transdisciplinary research of the effects of forest management on disturbance impacts and to improve the continuous education and capacity building as a means to update knowledge in practice.

5.2.2

Norwegian and Swedish public preferences for forest management practices underpinned by the self-construction of climate change

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Abstract

Forests' capacity to adapt to and mitigate climate change is influenced by management. Knowledge about how the public values the different forest management strategies is fundamental for policy- and other decision-makers. There is much debate in Norway and Sweden about how forests should be managed to supply a wide range of ecosystem services. We applied a binary discrete choice experiment through surveys conducted in these countries to elicit public preferences to changes from the status quo in key forest management attributes. These were: increased set-aside, proportion of uneven-aged tree stands, and tree composition - within privately-owned production forests. After controlling for latent psychological constructs denoting the degree of perceived spatial closeness and uncertainty to climate change, and altruistic environmental concerns, we assessed the willingness-to-pay (WTP) for selected management attributes using discrete econometric models. On average, the Norwegian public preferred larger set-asides and diversification of tree species but was indifferent to tree age distribution; the Swedish public favored changes in all three attributes. Norwegian and Swedish respondents attached the highest WTP to increasing set-aside areas by an average of 11.13 ~ 12.16 €/month and 10.4 ~ 14.58 €/month, respectively. Comparably, average WTP was much lower for other attributes, -2.43 ~ 1.22 €/month and 5.07 ~ 6.40 €/month for tree age distribution and 4.49 ~ 6.64 €/month and 6.93 ~ 8.18 €/month for tree composition. In both countries, the construction of climate change and its uncertainty affected WTP estimates with greater uncertainty being a strong determinant of preferring the status quo. Our results suggest a degree of public polarization regarding forest management, but unequivocal support for increasing set-aside areas in both countries.

5.2.3

From timber to carbon: stakeholder acceptance of policy measures supporting forest management transition in Finland

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Abstract

In this paper, we examine the acceptability of forest policy measures that could increase carbon sequestration in Finnish forests. Climate mitigation policy measures – forest fertilization, land use change fee, carbon payment, and voluntary carbon off-setting – are ways to translate the objective to forest management and have potential to reposition actors and their policy strategies. We develop a strategic understanding of social acceptance to understand how stakeholders in the forest sector come to accept climate mitigation policies, as well as aim to influence the acceptance of other actors, such as policymakers, forest owners, and the public, in relation to these policy measures. The study is based on qualitative analysis of 23 stakeholder interviews. The interviewed actors range from forest owners' association, wood industry companies and organisations, forest management service provides, nature conservation organisations, carbon compensation companies, and various governmental actors.

As existing frameworks on social acceptance do not explain how policy measures become accepted as part of the broader policy strategies of stakeholders, we suggest integrating the concept of the advocacy coalition framework with theories on social acceptance. The advocacy coalitions in Finnish forest policy have been identified in previous literature (e.g. Harrinkari et al. 2016). Based on previous studies, as well as our analysis, we identify two coalitions among the interviewed actors: the Forestry coalition, which aims to promote the economic development of the forest sector, and the Environmental coalition that focuses on biodiversity conservation. We suggest that these, and other core beliefs of the coalitions, impact their acceptance of individual policy measures. The advocacy coalition framework highlights how actors share resources, develop complementary strategies, and work together to align policies with their core beliefs. We show that acceptance of individual policy measures also forms part of broader strategic work and should not be evaluated in isolation.

5.2.4

Forest professionals' perceptions of uncertainty in forest planning

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Abstract

The intrinsic nature of forest planning problems is surrounded by uncertainty. Decision makers strive to improve their understanding of the sources of uncertainty and their impact on the decision-making process. However, uncertainty is rarely integrated into real-world forestry applications or into decision support tools that are used for managing the challenging nature of forest planning problems. We interviewed forestry professionals in order to identify the needs, interests, and challenges of managing uncertainty in forest planning. All the interviewees indicated the positive potential of a tool that could address some facets of uncertainty. This study highlights the next steps to incorporate uncertainty into the decision support systems for forest planning. However, our participants also acknowledged that uncertainty is not always fully understood in their organizations. To build the bridge between the practical needs of forestry professionals and the theoretical approaches, more effort should be placed on defining terminology and designing a framework for uncertainty analysis. This will provide the forestry community with a common language, help increase its general understanding, and improve communication between forestry researchers, forestry professionals, and other stakeholders.

5.2.5

Forest owners´ willingness to implement measures promoting water protection in boreal peatland forestry

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Abstract

Peatland forests provide wide range of ecosystem services, such as timber and water quality. However, current forest management practices have adverse water quality impacts. Private forest owners can promote water quality in peatlands through various water protection measures and alternative forest management practices. Currently, there is a lack of knowledge on forest owners´ opinions about water protection in peatland forestry.

We use a survey data on the Finnish forest owners (N = 1555) to examine their opinions on the role of financial support and advisory services as means to enhance their willingness to implement measures targeted at promoting water protection. Second, we analyze how different forest owners vary in their willingness to implement such measures.

To this end, we apply descriptive analysis and linear regression models. Preliminary results show that forest owners prefer financial support more than advisory services. However, their opinions are positive towards both policy instruments. The willingness to implement measures promoting water protection differ depending on motivations for forest ownership, both when offering advisory services and financial support. A significant factor explaining the willingness to advance water protection was forest owner´s positive attitude towards environmental protection. Forest owners who were satisfied with the current water protection regulation, were less interested in promoting water protection.

The results highlight the importance of financial support to forest owners. If society aims to promote water protection but the needed measures cause costs for forest owners, financial support is needed to compensate these costs. Additionally, many forest owners are currently lacking knowledge on how to take water quality impacts into account in their forest management decisions. The next step is to study what kind of new policy instruments would be needed to enhance forest owners´ willingness to implement measures promoting water protection in boreal peatland forestry.

5.2.6

Barriers and enablers for climate and biodiversity-smart forest management in Europe

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Abstract

The new 2021 EU forest strategy, together with the European Green Deal and the EU biodiversity strategy for 2030, is seen essential to achieve the EU's biodiversity objectives, adapting EU forests to the new conditions including weather extremes, as well as the EU's greenhouse gas (GHG) emission reduction target of at least 55% by 2030 and subsequent climate neutrality by 2050. In Europe, around 60% of forests are owned by several millions of private owners. Private forest ownership is still increasing due to the restitution process in Eastern European countries, community buy-outs in Western Europe and afforestation of agricultural land. Forest owners have their management approaches and objectives which might or not be aligned with European and country policy targets of promoting climate and biodiversity-smart (CBS) forest management. To design effective policies, policymakers should understand what current CBS forest management practices are implemented across Europe, what factors influence practitioners' decisions to implement those practices, and what are the barriers and enabling factors for the implementation of CBS forest management practices across Europe. This study undertakes an analysis of published literature (literature analysis) and a qualitative data collection through 27 semi-structured interviews with forest practitioners and key national experts in 9 countries in Europe, namely Finland, Italy, Romania, the Netherlands, United Kingdom, Italy, Lithuania, Germany, and Portugal, to identify current forest management approaches and trends across Europe. Forest management systems and silvicultural practices (e.g., regeneration approach, selection of forest reproductive material, thinning and cutting regimes, treatment of residues, soil treatment) are identified and associated with forest practitioners' types and regions where the practices are implemented. Barriers and enablers for the implementation of CBS forest management are identified. This study contributes to the Horizon Europe and Innovate UK funded project ForestPaths - Co-designing Holistic Forest-based Policy Pathways for Climate Change Mitigation.

Session 6.1 Sustainable use of forests

6.1.1

Exploring ecological drivers and responses of biodiversity to improve simulation studies.

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Abstract

Boreal forests are multifunctional as they provide a range of ecosystem services to human societies and provide habitat for non-human life. As the climate and biodiversity crises continue, pressure on production landscapes to increase multifunctionality is increasing and forest managers now need to understand the impact of management on the provision of services. Biodiversity is both an ecosystem service in itself and supports a range of other services which is why we need to characterize the tradeoffs between biodiversity and other ecosystem services. But this requires having a good definition to select indicators representative of biodiversity's many aspects when making forecasts.

Tools and models used in forest management planning to forecast the development of the forest have been primarily developed for economic and industrial use and may have limited capacity to characterize biodiversity. We explore this conflict through a comparison of the indicators used in forest management planning and the main definitions and theories in ecology. Through this comparison we highlight the opportunities to improve future biodiversity studies in forestry.

We found that some of the drivers and responses included in the ecological definition of biodiversity were underrepresented in forest planning studies. Indeed, spatial and temporal connectivity along with species and ecosystem functions were integrated in very few studies compared with structural and species indicators. This is mostly due to the use of proxies emanating from decision support systems dedicated to timber production and a lack of diverse methods to include different proxies.

We anticipate that our future research will elaborate on the use of biodiversity models that incorporate aspects of spatial and temporal connectivity along with indication of function and integrate it in a multifunctionality study.

6.1.2

Safe operating boundaries for boreal forest harvesting

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Abstract

Human societies are bounded by the limitations of planet Earth. This scientific fact, and the derived concept of strong sustainability, implies that ecological boundaries set by the biosphere are non-negotiable. Forest ecosystems have a specific limited capacity to provide ecosystem services and sustain biodiversity, determined by their current state, future conditions (e.g. climate), and management. To keep within this capacity requires using forests within their ecological boundaries. This implies forest harvesting at levels that allow for maintenance of natural capital. In this study, we used forest growth simulation and optimization tools to define a maximum harvesting level that effectively halts the decline in biodiversity, and eventually allows forest ecosystems to achieve a favourable conservation status. This analysis is carried out in heath forest types using open data separately for different forest vegetation zones at the Finnish national scale. We use the criteria from the assessment of threatened habitat types in Finland and define favourable conservation status as a state where forest habitat types will be removed from the Red List. The results show that if the society wants to keep forest harvesting within the safe boundaries, harvesting levels should be considerably below the maximum economically sustainable roundwood removals. The safe harvesting level varies among regions and among forest types. This study is the first serious attempt to concretely estimate how much harvesting boreal heath forests tolerate without the compromising their natural capital. The results clearly indicate that the aim of Finnish forest policy of harvesting near the maximum economically sustainable roundwood removals is not compatible with the concept of strong sustainability. These findings challenge the society to figure out just and effective ways to reduce timber harvesting. The potential economic loss from reducing harvesting will be compensated by considerable social and ecological gains.

6.1.3

Should I spare or should I share? A multifunctional assessment of Triad management in Finnish boreal forest landscapes

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Abstract

Land-use policies strive to enhance the sustainable use of natural resources. The Triad approach have been suggested to balance the social, ecological, and economic demands of forested landscapes. The core idea is to allocate landscape zones with specific management priorities to enhance multifunctionality at the landscape level, i.e., production (intensive management), multiple use (extensive management), and conservation (forest reserves). We tested the efficiency of the Triad approach and identified the respective proportion of above-mentioned zones needed to enhance multifunctionality in a Finnish forest landscape. Through a simulation and optimization framework, we explored a range of scenarios of the three zones and evaluated how changing their relative proportion impacted various biodiversity and ecosystem service indicators.

The results show that maximizing multifunctionality required 20 % forest area managed intensively, 50% extensively, and 30 % allocated to forest reserves. Such landscape zoning represented a good compromise between the studied multifunctionality components and maintained 61% of the maximum achievable economic value (timber production). Allocating specific proportion of the landscape to a management zone had distinctive effects on the optimized economic or multifunctionality values. Economic values were generally negatively associated with increasing proportions of reserves and positively associated with increased proportion of intensive management, while multifunctionality benefited from less intensive and more diverse management regimes.

Our results show the potential of the Triad approach in promoting forest multifunctionality, as well as a strong trade-off between economic value and multifunctionality. We conclude that restricting forest management into intensive, extensive, and reserve zones does not implicitly contribute to a positive overall forest multifunctionality; however, management still requires clear landscape objectives.

6.1.4

Review of research on forestry measures to sustain biodiversity in boreal forest ecosystems.

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Abstract

Maintaining forest biodiversity and ecosystems is central for ensuring sustainable forest management. Boreal forest ecosystems have been greatly affected by human use throughout time, with the current intensive forest management paradigm proven to cause biodiversity declines. At the same time, forest industry is important for value creation and employment in rural areas, and wood products can substitute fossil-based materials. The shifts towards the bioeconomy may lead to increased demand for wood materials and energy which in turn may intensify forestry with its consequences on ecosystem services. Upon forest management, environmental measures to inter alia preserve biodiversity are undertaken based on law and/or certification requirements. Despite the rich literature, the discussion about effectiveness of the measures is ongoing. Also, there is limited knowledge about the measures' cost-benefit which may hamper their effective implementation. We aim to fill part of these voids by reviewing the scientific literature of how boreal forestry's environmental measures affect biodiversity. Recognized methods for searches in scientific databases in addition to grey literature in English and Scandinavian languages resulted in more than 3000 papers on field studies, reviews, simulations, and modeling of the forest ecosystem biodiversity in the boreal zone, which after sorting ends up in 200-300 original papers related to the major in-situ measures like green tree and dead wood retention, buffer zones and key habitat preservation. Findings are categorized according to effects on species groups and threshold values are scrutinized. The analyses will give an updated overview of the practical biodiversity measures carried out by practitioners with associated costs and benefits. This is pivotal knowledge for operational forestry as well as for policymakers for preserving biodiversity and the ecosystems in the transition to the bioeconomy.

6.1.5

Input data resolution affects the quality of conservation prioritization

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Abstract

Detailed spatial data are craved for in land use planning and decision making to take both the needs of societies and the carrying capacity of nature into account. Novel data sources and processing techniques offer high hopes and possibilities. Spatial prioritization is a powerful tool for guiding land use planning. However, the prioritization results are affected by the used spatial resolution and the overall quality of input data. Even moderate resolution datasets can result in acceptable results, but more detailed input data ensure the visibility of smaller patterns. This study shows the effect of improving the spatial resolution forest data by means of detailed airborne remote sensing (RS) and novel machine learning methods.

The research was conducted in southern Finland in a study area consisting of a mosaic of intensively managed forests, recreational forests, and forest with strict conservation status. The entire forest area was covered with a RS-based tree map describing the tree-level attributes of the dominant canopy layer. We also mapped the location and size of downed deadwood in the study area by using airborne laser scanning data and an object-based mapping algorithm. For the needs of spatial prioritization done with Zonation software, the data were transformed into a regular grid with 16m cell size, and further aggregated into 32m, 48m, 64m, 80m, and 96m cell sizes. The differences between the 2% and 10% top fractions in each resolution were investigated further.

The spatial error of omission between the 16 m baseline and coarser resolutions ranged from 55% to 80% and had a significant impact on conservational error. Our results show that rare forest features tend to suffer the most from the increase of resolution in the prioritization process. Rare features, such as hot spots of keystone species European aspen, are lost with coarse resolutions.

Session 6.2 Climate-ecosystem interaction

6.2.1

Forest carbon stock budget development following extreme drought-induced dieback of coniferous stands in Central Europe.

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Abstract

The aim of this contribution is to analyze the scenarios of likely forest carbon budget development following the recent historically unprecedented dieback of coniferous stands in the Czech Republic. The drought-induced bark-beetle infestation resulted in record-high sanitary logging, turning Czech forestry from a long-term sink offsetting over 5% of the GHG emissions in the country to a significant source of CO_2 emissions in the recent (2018-2021) years. The calamity apparently peaked in 2020, while the felling and estimated emissions for 2021 indicate a general turnaround of the calamity in the country. The recent trend as well as scenarios of forest carbon budget development were analyzed using the nationally calibrated Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3). CBM-CFS3 is an aspatial, stand- and landscape-level modeling tool that simulates the dynamics of forest carbon stocks in living biomass, dead organic matter (litter and deadwood), and soil. It has been applied at the regional (NUTS3) spatial resolution. Besides the impact on carbon budget and emissions, the study quantifies the effect of adaptive forest management in terms of changes in tree species composition, harvest possibilities, and changes to forest structure. The model analysis indicates that Czech forestry may stabilize by the end of this decade. After that, it may generate a sustained carbon sink while improving its resilience by the gradual implementation of necessary adaptation measures that grant provisioning of all expected forest functions to society.

6.2.2

Disentangling the net climatic effects of moose browsing in early successional boreal forests

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Abstract

Moose is a predominant large herbivore in boreal forests and it shapes forest structure and composition. It can mediate boreal forest regeneration after timber harvest through selective browsing of tree species, and it alters land cover properties such as surface albedo, with direct implications for the climate system. A better knowledge of the interactions of the climate-forest-moose nexus can help to maximize climate change mitigation benefits of forests and associated ecosystem services, including timber value. However, despite increasing evidence of moose browsing influence on tree growth, its effects on carbon sequestration rates, tree composition and surface albedo remain largely unexplored. In this study, we used 11 years of empirical data from 44 pair-sites of herbivore exclosures within clear-cut forests in Norway to investigate how moose browsing alters aboveground tree biomass and albedo. We find a higher total aboveground tree biomass (mainly deciduous) in browsed than un-browsed forest plots, as moose browsing limited the growth of tree biomass. The effect of moose exclosure on relative tree abundances differed between sites, suggesting that moose browsing has stronger effects on forest structure than composition. At the same time, moose increased forest albedo relative to un-browsed forests, driving biophysical cooling. When averaged at regional levels, climate effects due to changes in biomass and albedo are of similar magnitude, but contributions can diverge in specific locations. In a region with intensive forestry operations and high moose density, CO2 emissions from moose browsing in post-harvested sites can be equal to about 40% of the annual emissions of fossil fuels from that region. Cooling effects from increased albedo can offset about two thirds of this impact. Given its influence on tree growth rates and climate impacts, management of moose browsing density should be integrated into forest management plans to optimize climate change mitigation and forest productivity

6.2.3

Reduction of land surface temperature associated with forest management in Fennoscandia

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Abstract

Forests affect the local climate through a variety of biophysical mechanisms. Observational and modelling studies have investigated the effects of forested vs. non-forested areas, but the influence of forest management on surface temperature has received far less attention owing to the inherent challenges to adapt climate models to cope with forest dynamics. Further, climate models are complex and highly parameterized, and the time and resource intensity of their use limit applications. The availability of simple yet reliable statistical models based on high resolution maps of forest attributes at various development stages can link individual forest management practices to local temperature changes, and ultimately support the design of improved strategies. In this study, we investigate how forest management influences local surface temperature (LST) in Fennoscandia through a set of machine learning algorithms. We find that more developed forests are typically associated with higher LST than young or undeveloped forests. The mean multi-model estimates from our statistical system can accurately reproduce the observed LST. Relative to the present state of Fennoscandian forests, an ideal scenario with fully developed forests is found to induce an annual mean warming of 0.26 ℃ (0.03/0.69 ℃), and an average cooling effect in the summer daytime from -0.85 to -0.23 ℃. On the contrary, a scenario with undeveloped forests induces an annual average cooling of -0.29 ℃ (-0.61/-0.01 ℃), but daytime warming in the summer that can be higher than 1 ℃. A weak annual mean cooling of -0.01 ℃ is attributed to historical forest harvest that occurred between 2015 and 2018, with an increased daytime temperature in summer of about 0.04 ℃. Overall, this approach is a flexible option to study effects of forest management on LST that can be applied at various scales and for alternative management scenarios, thereby helping to improve local management strategies with consideration of effects on local climate.

6.2.4

Understanding the drivers and trends of terrestrial ecosystem CO_2 fluxes across the boreal biome

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Abstract

The boreal biome is experiencing rapid changes with pronounced impacts on the terrestrial carbon cycle due to climate change. The greening of the boreal biome has been shown to correlate with increases in summertime carbon uptake in areas that are not undergoing major disturbances related to fires, permafrost thaw, and drought. However, during autumn months, carbon emissions may be increasing. Despite the importance of these boreal fluxes for global carbon budgets, we lack a comprehensive circumpolar understanding of their dynamics that would integrate the extent, magnitude, and drivers of these fluxes and their changes in different seasons and regions. Here, we aim to fill this knowledge gap by studying the drivers and spatiotemporal patterns of spring, summer, autumn, and winter carbon dioxide (CO_2) fluxes and budgets. We use a recently compiled database of monthly Arctic-Boreal terrestrial ecosystem CO_2 fluxes estimated with the eddy covariance, chamber, and snow diffusion techniques (ABCflux, n=3812). The database has 10 sites from larch forests, 40 from evergreen forests, 3 from deciduous broadleaf forests, 2 from mixed forests, and 25 from wetlands. The majority of these sites are in Europe and North America, and represent relatively unmanaged and undisturbed conditions and older ecosystems. We upscale CO_2 fluxes across the boreal biome over the past three decades using machine learning models and geospatial data. Our results suggest that the boreal biome is an increasing annual net ecosystem CO_2 sink, with both forests and wetlands acting as stronger sinks, both in Eurasia and North America. The increasing sink is driven by warmer and more productive conditions during early and peak growing season, however, autumn emissions have also increased. These results demonstrate the large biome-wide changes in boreal CO_2 fluxes and demonstrate their important role as a CO_2 sink in the contemporary global carbon cycle.

Special session 7.1 Radiation regime of boreal forests – measurements and models

7.1.2

Proximal imaging of small trees under ambient greenhouse conditions (PIA)

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Abstract

Recent advances in the miniaturization and production of remote sensing instrumentation, such as hyperspectral imaging systems and laser scanning devices, have led to a broadening of applications. For example, such instrumentation is now regularly incorporated into phenotyping infrastructures and commercial and research greenhouses. Studies conducted in these environments are typically concerned with food crops or model organisms and relating genomic variation to observable traits i.e., phenotyping. Controlled environments such as climate-regulated greenhouses also present opportunities to study the ecophysiology of individual trees over longer time scales, with the lessons learned and methods developed potentially applicable to outdoor conditions. In controlled conditions, trees can be subjected to environmental manipulations (e.g., drought) that are relevant to climate resilience or forest management scenarios and are difficult to achieve in situ. Here we present a Proximal Imaging stack for Ambient (PIA) greenhouse or outdoor conditions. PIA is centered around a Senop HSC-2 hyperspectral camera capable of operating over days and weeks and complemented by low cost lidar and thermal imaging sensors. Early results from measurements conducted on young Scots pine trees point to the additional spatial information content provided by hyperspectral imaging relative to leaf level spectral clip measurements. However, there are several technical hurdles to overcome before PIA can become operational indoor or out, including rigorous sensor characterization, developing a robust irradiance normalization scheme, building a data processing and capture pipeline, and integration of multiple sensors.

7.1.3

Leaf chlorophyll and carotenoid contents of European Aspen and their assessment by airborne imaging spectroscopy

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Abstract

The ongoing biodiversity decline underlines the need to monitor terrestrial biodiversity to support the planning of conservation, restoration and land-use. Remote sensing tools suitable for covering large land areas in a quantifiable, repeatable and comparable manner to monitor biodiversity indicators in both spatial and temporal dimensions are needed. European aspen (*Populus tremula*) is a foundation species and a good biodiversity indicator in boreal forests. The aim of this study was to evaluate the applicability of aerial imaging spectroscopy in the estimation of foliar chlorophyll and carotenoid contents in individual aspen trees in boreal forest region including both protected and non-protected areas in southern Finland. We analyzed the concentrations of chlorophyll and carotenoids in the upper canopy leaves by traditional laboratory methods and compared them with the upper canopy spectral reflectance of aspen trees. We found out that 1) chlorophyll and carotenoid contents had a high within species variability among aspen trees, 2) the accuracy of foliar chlorophyll and carotenoid content estimation in aspens by airborne hyperspectral imaging was reasonably good, 3) the red edge range was the most informative in estimation of chlorophyll content in aspen. Not all spectral variation is among-species variation, which needs to be considered when spectral diversity is used as an indicator of biodiversity.

7.1.4

Revealing fine-scale variability in boreal forest temperatures using a mechanistic microclimate model

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Abstract

Local temperature variations are important drivers of ecosystem functioning and species distribution in boreal forests. However, due to the coarse spatiotemporal resolution of climate data commonly applied in climate change impacts models, the potentially large variability in thermal conditions have been difficult to factor in to the models of e.g. forest fire risk index and species distribution models. Here, we aim to reveal temperature variability in boreal forest environments using a recent implementation of mechanistic microclimate model. We modelled the hourly microclimatic temperature variability in summer 2020 over three focal landscapes in southern, middle, and northern boreal forest environments in Finland at spatial resolution of 10 x 10 m. Data used for modelling consisted mostly of open source files collected by the different governmental organizations of Finland. The modeling revealed a substantial thermal variability over the landscapes, for example at the 0.15 m and 1.5 m heights the temperature ranges varied from 31 to 46 C and from 26.7 to 53.9 C.

The model validation over 150 microclimate stations showed good agreement between the measured and modelled temperature variation over the selected 2020 may-august time period. The root mean square error (RMSE) was found to be dependent on the landscape characteristics of the plant area index value. Our validation results for the three sites showed a RMSE of 2.71 – 3.88 °C at 0.15 m height and 2.62 – 3.36 at 1.5 m height when comparing the modelled and measured hourly microclimate data values. These results show the great potential of using mechanistic microclimate modeling to understand the thermal characteristics of boreal forest environments. Ultimately, high-resolution spatial microclimate data will help us to better understand e.g., the response of boreal species against climate and land use change and fine-scale variability of forest fire risk.

Session 7.2 Forest growth and regeneration

7.2.1

Are fast growth and drought tolerance two opposed properties in conifers? Scots pine case

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Abstract

Genetic degradation is a problem for the ecosystem, both ecologically and economically. The Swedish Forest is the outcome of a combination of natural regeneration and mainly human-driven planting with unenhanced and enhanced (breed) seeds from both Swedish and foreign origin. Little is known about the impact of breeding on present forest growth, wood quality, genetic diversity, and its adaptability and resilience. To answer this question, six Scots pine forests were selected. Three were naturally regenerated and three were planted with breed seeds originating from seed orchards. In those six sites buds were collected from a total of 600 trees. Those samples were genotyped with a 50K SNP-Array to conduct foliar endophytic biodiversity on the same DNA. Increment cores were collected from the same 600 trees to measure wood quality with X-ray absorption and diffraction (Silviscan, RISE). For assessing the resilience of those forests to climate change, seeds were collected, and a drought essay together with a root phenotyping experiment was conducted under controlled greenhouse conditions. The essay consisted of a new method using machine learning-based high throughput phenotyping to evaluate plant growth and development both in control and drought conditions. Root architecture was assessed at the end of the experiment to identify the genetic influence of root shape and its role in drought tolerance. At the end of the experiment, samples were collected from drought-tolerant and sensitive families to perform a transcriptomics and metabolomics analysis. This will give information of how Scots pine plants from northern Sweden adapt to drought conditions.

7.2.2

Forest management in British Columbia's boreal forest: the disconnect from traditional land use

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Abstract

Northeast British Columbia's (BC) 10+ M hectare boreal forest (54-60^{0}N; 120-123^{0}W) was a multi-aged mosaic ranging from pure broadleaves through mixedwoods to pure conifers. Forestry, oil and gas development, and wildfire have transformed much of the mosaic to conifers. This occurred, in part, due to the legal free growing standard (FG) where broadleaves are removed in favor of more valuable conifers. Forest simplification occurs and negatively impacts First Nations' traditional land use and values because of reduced diversity. Climate model projections indicate boreal forest regions are the most vulnerable global region to climate change and conifers are at greater risk than broadleaves. We initiated trials at three geographically separated sites to determine the impact of broadleaves (*Populus tremuloides*, *Betula papyrifera*) on conifer (*Picea glauca*) productivity by comparing conifer growth in the mixedwood to pure conifer stand growth projected in BC's government accepted model used in timber supply determinations. The primary FG assumption is conifer productivity is reduced in mixedwoods. After a decade, broadleaf densities at the sites varied from about 3000 to 7500 stems per ha (SPH) well above the 1000 SPH considered acceptable by FG criteria. Conifer diameter growth was not impacted by broadleaf competition, and conifer productivity in mixedwoods met or exceeded model expectations for a pure conifer stand of the same age on the site. Retaining broadleaves did not impair spruce growth. Total productivity increased, as did ecological and social benefits thereby reinforcing the BC Government's commitment to UNDRIP: respecting First Nations' ties to the land. This management approach meets First Nations' environmental vision, and government/forest company economic expectations while enhancing ecological values, productivity and stand resilience. Clearly, mixedwoods are beneficial. However, FG criteria should be changed to promote boreal mixedwood management and enhance the potential to acclimate to changing climates.

7.2.3

How does a changing climate influence seed production in boreal conifers? Findings from observational and experimental approaches.

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Abstract

Boreal forests are vulnerable to climate change and impacts on conifer tree reproduction will affect forest regeneration and ecosystem dynamics. Boreal conifers undergo mast-seeding, the spatially synchronous and highly temporally variable production of seed crops by a population of perennial plants, where large reproductive events are synchronized by climatic conditions occurring one to three years prior to seed maturation. There are a range of predictions for how climate change will affect tree reproduction, from minimal effects to strong negative or positive effects. I will test these alternative predictions using empirical data from long-term field observations and experiments. Fifty-five years of data on tree reproduction in northern North American forests (1960-2014; n=84 datasets, primarily the genus *Picea*) shows variability in annual reproduction is unchanged over time, despite warming, because the key driver of mast-seeding is the difference in temperature between years (and this difference has been resistant to change over time) as well as a one-year lag in tree reproduction. Experimental data on *Picea mariana* and *Larix laricina* at the US Department of Energy's Spruce and Peatland Response Under Changing Environment (SPRUCE) project creates alternative climate scenarios. SPRUCE consists of ten open-topped chambers (12-m wide, 8-m high) with five temperature treatments (+0°C (unheated), +2.25°C, +4.5°C, +6.75°C, +9°C) paired with two CO_2 treatments (+0 ppm, +500 ppm). These data, collected annually from 2017-2022, show cone production is much greater under elevated CO_2 regardless of temperature, with the exception that under extreme warming cone production there is no/very low cone production. Understanding how tree reproduction is affected by climate change is important, because tree planting is a nature-based solution proposed to mitigate climate change and relies on the availability of seed, and seeds provide food for a variety of consumers (e.g., small mammals, birds, insects, and people).

7.2.4

Fast recovery of suppressed Norway spruce trees after selection harvesting on a drained peatland forest site

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Abstract

Continuous cover forestry (CCF) has been promoted as an environmentally sustainable option for drained peatlands. The CCF management has been challenged due to potentially lower tree growth compared to traditional even-aged management, especially with suppressed trees that are released during a selection harvesting under CCF management.

Our objective was to quantify the time lag of stem diameter growth response of suppressed Norway spruce trees (Picea abies Karst.) after a selection harvesting. We also tested if the carbon assimilation of the trees increased immediately after selection harvesting. We used radial increment cores to estimate the impact of selection harvesting on the diameter growth and intrinsic water use efficiency (iWUE). We measured carbon isotope composition (δ13C) of wood, to quantify how the reduced competition between trees altered iWUE and its components, the photosynthetic rate (A) and stomatal conductance (g).

The study was conducted in the Lettosuo experimental site on fertile forestry drained peatland area in southern Finland. Approximately 70 % of the stand area (18.5 ha) was harvested by applying selection harvesting, and the rest of the area was divided to intact control area and to clear-cut area. All the target trees grew in the similar competitive position before selection harvesting.

Our results show that there was a delay with the diameter growth of the suppressed trees to selection harvesting, whereas the most significant growth-enhancing effect occurred three-four years after selection harvesting. In contrast to the delay in the increment, the photosynthetic rate relative to stomatal conductance increased immediately after selection harvesting, as shown by the instant 2.5‰ increase in δ13C.

Our results show that carbon uptake increased immediately for suppressed Norway spruce trees after selection harvesting, but the harvest did not induce a clear increase in diameter growth during the first years after the harvest.

7.2.5.

The quasi-pipe (qPipe) model – a convenient allometry for estimating the amount of leaves per tree

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Abstract

The estimation of the amount of leaves on a tree (tree leaf amount) is important as a component of the estimation of the amount of leaves in a forest, as it serves as ground-truth data for remotely-sensed leaf area index (LAI) measured over a wide area. Allometric method is a major method for estimating the tree leaf amount, and one of well-known allometric models for estimating the tree leaf amount is the pipe model of the tree form, which quantifies the approximate proportionality between the tree leaf amount and the stem cross-sectional area at the crown base. However, the pipe model allometry has little been used as the method for non-destructively estimating the tree leaf amount, as the method involves tree climbing. In the present study we introduce the quasi-pipe (qPipe) model allometry, which relates the tree leaf amount with tree dimensions measurable on the forest floor, i.e., diameter at breast height, tree height, and crown-base height of each tree. The validity of the qPipe model has been reported only for a birch and an evergreen conifer species. In this study we show that the qPipe model is comparable to the original pipe model, by using published/unpublished data for more than 900 trees comprising ~150 species collected between tropical rainforests and boreal forests. We also examined another issue that the pipe model predicts, i.e., the ratio of the amount of leaves per unit area of stem cross-section at the crown base (the pipe model ratio) being constant among trees with different size. We found that the constant pipe model ratio held for tree leaf area, but not for tree leaf dry mass. Furthermore, we also show the that the pipe model and the qPipe model allometries for tree leaf area are very similar among different plant functional types.

7.2.6

Masting in forests: a playful introduction

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Abstract

Following the example of the European Geosciences Union's Games Jam sessions, I intend to use a little game to introduce masting to the attendants of the session. Masting is the intermittent, irregular seed production of certain plant species, such as oaks, beech, and chestnuts in the Fagaceae family. In some years, called mast years, these species produce many seeds, while in other years they produce few or none. Although the scientific background of masting is still debated, it is influenced by the weather and the synchrony of flowering in the forest, which influence available resources for masting and pollination efficiency. Each attendant, or player, will represent an individual oak tree in the forest and in each round, or year, accumulate resources depending on the weather in that year. In each round, the players decide individually whether to use these resources for growth, for flowering, or for storage. If the players manage to coordinate their flowering efforts, the flowers will turn into acorns. However, if too much acorn is produced, the population of species living on acorns will also increase, decimating the number of healthy acorns. The aim of the game is to maintain the intensity and frequency of mast years in the forests by cooperating with other players. As climate change affects masting via changes in the start and length of the growing season, the players can try out different climate scenarios and see in which one it is the most difficult to maintain masting patterns.

Session 8.1 Modelling and managing damage risks

8.1.1

Optimizing the regeneration of spruce-dominated stands infected by *Heterobasidion* root rot

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Abstract

Heterobasidion root rot is a destructive disease causing extensive damage to boreal conifer forests. In spruce stands, the causative fungus, *Heterobasidion parviporum*, spreads among the root systems of trees, as well as through spores germinating on freshly cut stump surfaces. *Heterobasidion* root rot degrades sawlog-caliber wood to pulp or energy use, and makes forest stands less resistant to, e.g., wind damage. These issues are expected to worsen as climate change proceeds and the pathogen spreads to new forest sites. In this work, we present a precision-forestry method for regenerating infected stands, which enables one to prevent the spread of the disease at infected sites and provides high climate change mitigation or economical values. First, using stem-specific data from harvester machines on how spruce trees were cut into logs, we identify the regions of a stand where root rot was present upon final felling. Then, by generalizing simulations of stand growth for various alternative tree species and of *Heterobasidion* dynamics, we determine the optimal microstand configuration in terms of carbon sequestration or net income to the forest owner. We present examples of optimized regeneration plans and expected benefits and compare them to regenerating the infected stands using prevailing approaches. Finally, we outline the prospects of putting the optimization method to practice and offering the method to forest owners in Finland.

8.1.2

Modeling feedbacks between fire and forest management at the landscape scale under historical and future climate scenarios

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Abstract

Prior to European colonization of western North America, cultural burning and natural lightning ignitions created dynamic, patchy mosaics of different successional forest and non-forest states that significantly influenced the size and severity of subsequent fires. Fire exclusion and other management practices over the last century have increased the volume and continuity of fuels across the landscape, rendering forests vulnerable to the large and high severity fires seen today. These changes paired with changing wildfire and climatic regimes are forcing land managers and policy makers to evaluate how management practices can restore resiliency and mitigate fire behaviour across the landscape. Here, we present REBURN, a forest and fuel succession state-transition modeling platform that is coupled with a fire growth model. As part of the Pacific Institution for Climate Solutions (PICS) Wildfire and Carbon (WFC) project, the model from eastern Washington has been adapted to a study area in British Columbia's Okanagan Highlands. We have run the model for several millennia under two historical scenarios – with and without aspen. Deciduous forest patches are often less flammable, and early seral aspen conditions may have played a vital role in historical landscape resilience. Modelling results provide insights on the historical range of variation of forest and non-forest conditions, and the role of aspen in mitigating landscape-level fire behavior. We are now expanding REBURN to include forest management and the influence of climate change, through changes to weather inputs and shifts in species' ranges. The future scenarios will contribute to our understanding of how adaptation actions can foster resiliency. The results from this research will inform forest managers and policy makers on how management and application of landscape resilience principles can mitigate fire behavior and create resilient landscapes under a future climate.

8.1.3

Improving the risk modelling of wind and snow damage for supporting decision making in forest planning in Sweden

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Abstract

The purpose of this study was to create an improved risk model of wind and snow damage for Swedish forests aimed to be implemented in the Swedish forest decision support system Heureka. This was done by testing the usability of stand attributes together with spatial and weather variables and data stratification in empirical risk modelling. In the modelling, we used 1 606 damaged and 57 988 not damaged plots monitored between 2004–2020 by the Swedish NFI (National Forest Inventory), including plots with a mean tree height > 5 m and a total basal area > 7 m^2. Tested prediction variables included height above sea level, stand attributes and neighborhood information measured from NFI plots and weather variables. We will also test the stand neighborhood information based on Lidar data. The weather data was extrapolated from the 2015–2020 daily weather database (6.25 km^2 grid cells). We created prediction models using both Generalized Linear Model (GLM) and General Additive Model (GAM) for the whole Sweden and by dividing NFI data into two geographical areas: the middle-south and the north. The most important variables included in the best models were: height difference, snow depth, time since thinning, dominant species, precipitation, maximum wind speed, most common wind direction, and soil texture. Some of the variables, including snow depth and maximum wind speed, changed their weight and significance between different geographical areas. The AUC values for the whole of Sweden, middle-south and north were 0.72, 0.73 and 0.751 using GLM and 0.74, 0.747 and 0.758 using GAM. Based on our study, we recommend including both the spatial information on stand neighborhood and weather information in risk models. These are missing from the current risk model in the Heureka system. In addition, in this study the stratification of the data based on the geographical location improved risk prediction.

Session 8.2 Laser scanning and point clouds I

8.2.1

Detection of tree growth and changes in tree and forest structures by utilizing terrestrial laser scanning point clouds

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Abstract

Forests are dynamic ecosystems under constant change, with the most natural reason for change being the tree growth. The occurrence of changes as well as factors behind and resulting from them are of interest to many. Important topics are e.g., allocation of tree growth, up to date information about forest resources, the effects of tree growth to carbon sequestration potential of forests and quality of timber.

Typically tree growth has been determined by performing repeated measurements of basic tree attributes. However, more in detail and accurate information from tree growth as well as changes in the stem form and structure of the trees is needed to be able to further understand the development of trees and forests in different conditions and their reactions to the changing environment.

Terrestrial laser scanning (TLS) allows one to characterize trees and their surrounding environment on millimeter scale. This study presents results from the use of TLS point cloud based automated tree detection and measurement methods. The results show the ability of the used method to determine changes in attributes such as diameter, height and volume of individual trees as well as allow one to successfully quantify statistically significant changes resulting from tree growth in different growing conditions both in stem form of trees and forest structures.

When investigating interactions between tree growth and its neighborhood from the point clouds, clear correlations were found between increments in stem dimensions and detailed 3D characterizations describing crown structure and competition. Observing seasonal increment in tree structures was also possible with TLS data, if a certain minimum threshold for the increase is exceeded to ensure measurement accuracy. The findings show the capability of TLS point clouds to measure tree growth and characterize changes in forest structure as well as improve understanding of the processes related to them.

8.2.2

Monitoring Species-specific Response to Competition at Tree-level Using Multisensorial Point Cloud data in Boreal Forests

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Abstract

Growth is the main driver of the tree structure and is regulated by the competition between adjacent trees. A tree's response to the change in the availability of light, water, and nutrients varies between different tree species. Hence, characterizing species-specific response to competition at the tree-level and their changes over time plays a crucial role in understanding tree growth dynamics. Conventional methods to estimate distance-dependent competition indices (CIs) of individual trees can be labor-intensive and time-consuming, particularly for CIs based on crown characteristics. This study aimed to monitor species-specific stem and crown-based CIs using multisensorial point cloud data of terrestrial laser scanning data (TLS) and Helicopter borne laser scanning (HeliALS) from 2014 and 2021. This research was conducted in Evo, Finland over 22 rectangular sample plots with a size of 32 m×32 m where the Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* (L.) H.Karts.), and birch (*Betula* sp.) are the dominant tree species. TLS data were processed to estimate stem volume (V), and basal area at diameter at breast height of 1.30 m (BA1.30) and 0.6 of tree height (BA06h) using individual tree stem point clouds. HeliALS, given its ability to provide large-scale georeferenced point clouds and complementary top view to the TLS data, was employed to obtain individual tree crown points. They were combined with the TLS crown points to compute crown metrics of projection area (CA), volume (CV), and crown surface area (CS). The well-known distance dependent Hegyi index was used to quantify CIs based on these stem and crown metrics. Linear mixed effect modeling was used to understand how the response to competition differed between tree species during the monitoring period. Our results provide useful information about tree growth in response to competition and its variation between forests with different dominant tree species.

8.2.3

Estimating the amount and distribution of forest biomass burned in controlled burnings with bitemporal terrestrial laser scanning

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Abstract

Fires are among the most significant disturbances reducing forest biomass and evaluating the effects of fire on boreal forest biomass and carbon stock is important in terms of climate change mitigation. To quantify the amount of biomass burned in forest fires, bitemporal measurements (i.e., pre- and post-fire) are required, but due to the unpredictable nature of wildfires, this can be difficult. Therefore, controlled burnings offer a great opportunity to evaluate the changes in biomass.

The aim of this study is to estimate the amount and distribution of burned forest biomass with terrestrial laser scanning (TLS). TLS provides accurately positioned 3D point clouds of trees and ground vegetation, and with measurements before and after the controlled burnings, even the smallest changes in biomass can be detected. The study also investigates factors that may affect the amount of burned biomass and spatial autocorrelation. The study area consists of 9 study sites of about one hectare across southern Finland.

According to the preliminary results, changes in biomass can well be estimated with TLS-based surface differencing. In the total study area, the biomass decreased by an average of 1040 m^3/ha. A large standard deviation (960 m^3/ha) displays the diversity of the study sites. The amount of burned ground vegetation significantly differed with varying tree height and diameter, crown surface area as well as elevation above sea level and slope. This indicates that forest structure and topography have an effect.

In Finland, only the vegetation on the forest floor is burned during the controlled burnings. Therefore, the focus of this study is on the changes in ground vegetation, which has received less attention in previous research. Since the ground and surface fires are more common in boreal forests than high-intensity crown fires, this study brings an important addition to forest fire research.

Session 9.2 Laser scanning and point clouds II

9.2.1

Creating countrywide tree maps with airborne laser scanning and ground measurements with a bootstrapping approach

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Abstract

Creating structurally representative tree maps from large areas would be a significant step towards the European Commission's goal of creating a biodiversity-oriented digital twin of the Earth's forests. With sufficient local precision, such a digital twin could be used also as a tool for making forest management decisions at the local level.

Individual tree detection (ITD) applied to airborne laser scanning (ALS) data can be used to create tree maps, but smaller trees hiding under the tree canopy as well as clustered trees tend to be undetected, resulting in too much spatial regularity in the tree patterns.

Using 5 pts/m^2 ALS data, soon available for the whole of Finland, and ground measurements from about 450 plots in two locations, we have developed and validated a method for correcting for the missing trees and false discoveries using a computationally efficient tree-bootstrapping method. With the corrections, the tree maps accurately reproduce the stem number, spatial pattern, and tree height and diameter distributions. The resulting tree map can be used, e.g., accurately calculate summary statistics related to the structural aspects of biodiversity, which can in turn be used to make informed decisions when managing forests.

9.2.2

The same airborne laser scanning based model of a stand attribute can be used in forests treated with different silvicultural management systems

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Abstract

Interest towards continuous cover forestry (CCF) has been increased rapidly during recent years in Finland. CCF (uneven-aged management) has been examined from various viewpoints in Finland, but forest inventory applications are mostly lacking, also internationally. This holds especially for remote sensing-based applications. On the other hand, airborne laser scanning (ALS) data has been widely used for predicting forest characteristics such as size-distribution and vertical forest structure which are closely related to forest information needs of CCF.

Here we applied area-based approach of ALS to predict a set of essential stand attributes in a CCF forest management experiment in Katajamäki, Finland. Here our main aim was to test whether stands under different management systems can be included to the same attribute model. The accuracy of the predicted attributes was compared to other management systems of the same experiment including sheltertree stands and no-management stands. We also compared and discussed our results in relation to even-aged stand attribute predictions applying separate operational forestry study data near Katajamäki.

The results showed that forest data from different management systems can be combined to a single model of a stand attribute, i.e., ALS metrics can take into account differences in forest structure between different management systems. The accuracy of predicted attributes was comparable in CCF plots to other management alternatives of the experiment. The accuracy was also comparable to even-aged forests.

The results of this study were promising; the stand attributes of forests managed by CCF can be predicted correspondingly as in other management systems. Therefore, it may also be no need to stratify forest landscape according to different management systems for forest inventory. It should though be remembered that the study area was small, managed already in 1980's and the considered attributes may not be exhaustive for CCF.

9.2.3

Understanding tree growth allometry using multisensorial point clouds

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Abstract

Understanding tree growth allometry enhances eco-physiological or structural-function tree-level growth models. The generic allometric relationship usually concentrates on tree size, resulting in oversimplified metabolic scaling. The inclusion of crown structures can effectively contribute to reprojecting tree growth given their role in controlling the competition status of trees and biomass allocation. Terrestrial laser scanning (TLS) has successfully been used for tree growth analysis by consecutive measurements over time. However, its application is limited because of local spatial extent and occlusion ranging up to the canopy. Helicopter-borne laser scanning (HeliLS) can provide a complementary viewpoint of TLS at wide coverage while associated with attenuation in dense canopy forests. This study exploits the advantage of TLS in measuring tree stem and the combination of TLS and HeliLS crown points in measuring crown structures at two points in time (2014 and 2021). We aimed to understand how stem volume growth (ΔV) is affected by initial stem volume (V) and crown structure development (ΔC). The study was conducted in Evo, Finland over 22 square sample plots (1 024 m^2). Normalized point clouds were co-registered at each time and processed into individual trees by marker-controlled watershed segmentation. The Hausdorff distance was implemented to match trees in 2014 with corresponding ones in 2021. TLS-derived trees were classified into the crown and stem points where the latter was used in estimating the V based on the Huber formula and ΔV. Similarly, HeliLS-derived trees were filtered to exclude under-canopy vegetation, and their combination with TLS crown points was used to estimate crown metrics and their change over time including 2D projection area (ΔCA_{2D}), surface area (ΔCA_{3D}), and volume (ΔCV). Mixed-effect models were applied to determine mentioned allometric relationship. Our results emphasize the importance of crown structure in stands dynamic and promote further studies at a larger scale.

9.2.4

Developing nonlinear additive tree crown width models based on decomposed competition index and tree variables

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Abstract

Crown development is closely related to the biomass and growth rate of the tree. Crown width (CW) is an important covariable in forest growth and yield models and forest management. So far, various CW models have been proposed, however, limited studies have explicitly focused on additive and inherent correlation of crown components and total CW as well as the influence of competition on the crown radius from the corresponding direction. In this study, we used two model systems i.e., aggregation method system (AMS) and disaggregation method system (DMS), to develop crown width additive model systems. For calculating spatially explicit competition index (CI), four neighbor trees selection methods were evaluated. According to the principle of decomposition of a force, CI was decomposed into four cardinal directions, and added into model systems. Our results showed that the power model form was more proper for our data to fit CW growth. For each crown radius and total CW, height to the diameter at breast height (HDR) and basal area of trees larger than the subject tree (BAL) significantly contributed to the increase of prediction accuracy. The 3 m fixed radius was the optimal among the four neighborhoods selection ways. After adding decomposed competition Hegyi index into model systems AMS and DMS, the prediction accuracy of the model had significant improvements. Out of the model systems evaluated, AMS based on decomposed CI provided the best performance as well as considered the inherent correlation and additivity properties. Our study highlighted the importance of decomposed CI in tree CW modelling for additive model system. This paper focused more on the methodology and could be applied to other species or stands.

Session 10.2 Evaluating damage risks to forests

10.2.1

Effects of spatial arrangement on disturbance risk under two alternative management strategies

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Abstract

Climate change and increasing disturbances are challenging forests, highlighting the need for resilient forest management strategies. Continuous cover forestry (CCF) is frequently proposed in this context. Avoiding clearcuts and fostering a multi-age structure is seen as not only beneficial for biodiversity but also associated with a lower disturbance risk. A transition towards CCF is however not likely to happen for large areas of forest at once, but rather on the level of individual forest owners or stands. As disturbance risks in a stand are affected not only by the condition of the stand itself but also by that of its neighbors, we are interested in how such a mosaic of different management strategies would affect disturbance risks.

Using the spatially explicit forest landscape model (iLand), which allows for the dynamic simulation of disturbances (specifically wind and bark beetle) and forest management, we investigated the impact of different spatial arrangements of even-aged and uneven-aged management in a 45 500 ha landscape in Southern Finland. We simulated the entire landscape under either management and intermixed the two strategies either on the level of individual stands or in larger patches (50 ha).

We found tree height, stand volume, and share of spruce to be factors of particular importance related to the stand itself, which, contrary to initial assumptions, also caused higher disturbance impacts in the pure CCF scenario relative to the clearcut system. Clustering the two management alternatives in larger patches resulted in lower disturbance values than mixing them at the level of individual stands. Neighborhood effects were of particular importance when considering wind disturbance, as stand edges are a major factor in this regard. This highlights the need to consider the condition of surrounding forests as well as of the target stand when introducing alternative management strategies.

10.2.2

Resilience to wind disturbance in production forests: a modelling case study from south-western Finland

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Abstract

In Europe, the frequency and intensity of disturbances has been increasing in recent decades. In the light of expanding demand for a variety of ecosystem services provided by forests, the resilience of these ecosystems is of growing interest. This study focuses on the resilience of forest ecosystem services in a region dominated by even-aged production forests, examining the short- to long-term effects of a single disturbance event. In a 27 000 km^2 region in south-western Finland, we model the impacts of a severe wind disturbance that occurred in 2001. The storm event damaged 7.3 million m^3 of timber, equivalent to the annual harvest level. The process-based forest model PREBAS is initialised with national forest inventory (NFI) field data acquired prior to the storm event, and the plot-level disturbance impacts are introduced based on an extensive special inventory conducted immediately after the disturbance. We will analyse the effect of the storm event and the ensuing management on a range of forest variables and ecosystem services: growth, age structure, C storage in biomass and soils, available and harvested timber assortments, deadwood volume, biodiversity indicators, and the supply of non-wood products. Resilience will be quantified using the measures of perturbation and recovery rate of the variables of interest. The modelling framework will be validated against subsequent NFI plot data. We will apply a range of scenarios, considering multiple levels of disturbance intensity, the extent of salvage logging, and different post-disturbance 'regular' management approaches. The results of the study will support the formulation of post-disturbance management measures which increase forest resilience and maintain the long-term provision of ecosystem services.

10.2.3

Modeling risks of climate-driven wildfires in boreal forest: the FLAM approach

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Abstract

Extreme forest fires have been a historic concern in the forests of Canada, the Russian Federation, and the USA, and are now an increasing threat in boreal Europe. We will present approaches to modeling wildfire dynamics using the wildFire cLimate impacts and Adaptation Model (FLAM) being developed at the International Institute of Applied Systems Analysis (IIASA). FLAM operates on a daily time step and uses mechanistic algorithms to parametrize the impacts of climate, human activities, and fuel availability on wildfire probabilities, frequencies, and burned areas. Model validation on historical GIS and remote sensing data and future projections under climate change scenarios will be discussed at various scales and resolutions for the boreal forest. We will present modeling results for the boreal forest, including: (i) simulation of burned areas and adaptation options; (ii) projections of burned areas driven by climate change scenarios until 2100; (iii) regional variability and driving forces behind forest fires in Sweden. Our results support international analyses that, irrespective of changes in management, it is evident that climate change is very likely to increase the frequency and impact of wildland fires in the coming decades, also in the boreal forest.

10.2.4

Modeling predisposition of boreal Norway spruce forests to bark beetle infestations

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Abstract

Boreal forests are experiencing increasing problems with insect pests, connected with extreme weather events. There is an urgent need for better understanding and development of efficient means for assessing the occurrence and severity of bark beetle infestations and their relationship with stand and site characteristics, topography, and other natural disturbances (e.g., wind damage and drought), and climatic factors. Our main goal was to develop methods for predicting population shifts of the European spruce bark beetle (*Ips typographus* L.) and mortality of Norway spruce (*Picea abies* (L.) Karst.) caused by various factors predisposing bark beetle infestations in stands.

To develop these methods, a specific area damaged by a severe thunderstorm event in 2010 was investigated in southeastern Finland. Both the conserved and managed forests were considered. The compound factors investigated were: 1) stand characteristics, 2) infestation symptoms of spruce, 3) annual dynamics of damage spots, 4) degree day sums and drought, 5) soil type and 6) topography. Risk prediction was based on estimates of a beetle population level, fluctuating according to optimal conditions. Stem and crown symptoms were annually assessed visually, classified into three or four infestation classes, and represented as damage score values. Low-cost UAV remote sensing datasets provided a data on tree vitality.

We found that one of the most important variables predicting damage score value was a distance to the nearest storm damaged area. High degree day sums of summer months increased bark beetle performance, thus conducting to spruce decline. We suggest that damage scoring at the plot level, stand variables, and environmental data (climate, site) are together used in terrestrial and aerial monitoring systems of forest health, to produce risk maps and risk models to support decision-making in forestry and promote climate-smart forest management.

Session 11.2 Ecosystem services under pressure

11.2.1

Combining scientific and local knowledge improves the evaluation of future forest ecosystem services

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Abstract

Forest scenario analysis can help tackle sustainability issues by generating insight into the potential long-term effects of present-day management. In northern Sweden, forests provide important benefits including climate change mitigation, biodiversity conservation, reindeer husbandry, local livelihoods, and recreation. Informed by local stakeholders' views on how forests can be enabled to deliver these benefits, we created four forest management scenarios: the close-to-nature scenario (CTN) which emphasises biodiversity conservation, the classic management scenario (CLA) optimising the forests' net present value, the intensified scenario (INT) maximising harvested wood from the forest, and the combined scenario (COM) applying a combination of measures from the CTN and INT. The scenarios were applied to the local forest landscape and modelled over a 100-year simulation period, and the results of the modelling were then evaluated by a diverse group of stakeholders. For most ecosystem services, there was a time lag of 10–50 years before noticeable effects and differences between the scenarios became evident, highlighting the need to consider both the short- and long-term effects of forest management. Evaluation by the stakeholders put the modelled results into a local context. They raised considerations relating to wildlife and hunting, climate change risks, social acceptability, and conflict, highlighting the value of evaluating the scenarios qualitatively as well as quantitatively. Overall, stakeholders thought that the CTN and CLA scenarios promoted more ecosystem services and posed fewer climate risks, while also creating less conflict among stakeholders. Our results emphasise the value of combining scientific and local knowledge when developing and evaluating future forest scenarios.

11.2.2

CLIMB-FOREST project: Holistic account of forest climate effects from afforestation and modified management

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Abstract

Until recently, EU policies considered forests to be carbon neutral due to the equal uptake and release of carbon dioxide upon photosynthetic growth and harvesting. Since a recent paradigm-shift, EU also considers carbon storage in long-lasting wood products and carbon accumulated in old-growth forest ecosystems. However, many interacting processes in forest ecosystems are still omitted or too simplistic, for consideration of the true extent of climate effects of forests. Namely, there are also emissions of the greenhouse gases methane and nitrous oxide, short-lived climate forcers and biophysical effects from albedo changes and latent and sensible heat fluxes. These processes are intertwined and influence the climate mitigation efficacy of forests in a complicated manner.

The CLImate Mitigation and Bioeconomy pathways for sustainable FORESTry (CLIMB-FOREST) EU Horizon Europe project (2022-2027) provides knowledge towards alternative forest management options for entire Europe, in collaboration with local stakeholders representing a broad range of interests. This is done for various climate and socioeconomic scenarios to mitigate climate change while preserving biodiversity and ecosystem functionality. We take a holistic view on climate effects from empiric data as well as from results of an advanced coupled vegetation and earth-system model.

We present first results of the climate effects and highlight their complexity for a range of management alternatives in boreal regions. For example, introducing broadleaved trees in a coniferous forest is promoting forest resilience and stronger cooling from more effective solar light scattering and larger latent heat flux of broadleaved trees. On the other hand, their higher evapotranspiration might lead to an accelerated soil moisture depletion and reduced emissions of monoterpenes, which is warming the climate. Terpenes namely produce aerosol particles, which are effective cooling agents. Hence, better insight of climate effects is a prerequisite before policy makers can use forests as a tool for mitigating climate change.

11.2.3

Future development of European forests reveals limited synergies and trade-offs among ecosystem services

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Abstract

European forests have been a continuous carbon sink for around seven decades despite regular timber harvests. However, the state and development of forests is being increasingly challenged by growing large-scale disturbances due to ongoing climate change and increasing societal demands for timber, forest carbon sequestration, and other non-wood ecosystem services. In particular, the ongoing biodiversity crisis and the key role forests play in terrestrial biodiversity imply more proactive management to maintain and enhance forest biodiversity at all levels. We use current national forest inventory data from over 20 000 inventory plots in five European countries to model digital twins of present forests until the year 2100 under a wide range of management scenarios. On basis of the model outputs, we quantify a large set of ecosystem services and evaluate their relationships using principal component and correlation analyses. We show that carbon stocks of living trees, and biodiversity are assigned to independent components and show no correlations, indicating that managing forests for carbon stocks will not facilitate forests diversity simultaneously and vice versa. Moreover, various ecosystem services that represent significant biodiversity indicators such as deadwood, tree species diversity and forest stand age show none or little synergies among each other. Varied timber harvest level had only slight effects on the various ecosystem services including biomass carbon stocks, biodiversity, and deadwood. In Austrian forest, increasing harvest level decreases carbon stocks and stand age. In the course of time timber harvest levels negatively affect carbon stocks and stand age in Finnish forests whereas not so in other countries.

11.2.4

Consequences of moose browsing on timber production, management and multiple societal returns

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Abstract

Modern forestry practices based on clearcuts provide ample food for deer and is a key driver for maintaining a dense and highly reproductive moose population in the Nordic countries. However, moose browsing causes heavy damages on pine. Through browsing, mortality of young trees increases while height growth is temporarily reduced, which cause the future stand density and wood production to be lower. Suboptimal density and growth setbacks pull the overall rotation length in different directions. Despite the hands-on knowledge of impacts of moose browsing and the long-term discussion about the optimal moose density, the scientific quantitative understanding of the moose-density consequences on forestry is yet limited. However, high moose density infers multiple types of costs through its impacts on long-term growth, yield, profits, and non-timber values. We attempt to fill part of this void by studying the impacts of browsing damage on growth, management, timber yields, economic returns, carbon sequestration and biodiversity status. We do this by implementing new browsing damage functions in the individual-tree growth and yield simulator TreeSim and finding the shifts in optimal management with different moose densities reflecting observed ranges. TreeSim simulates tree and stand volumes based on functions for ingrowth, height and diameter growth and mortality, in addition to management alternatives. Through the damage functions, higher mortality and height growth reduction caused by browsing are simulated. Starting from regeneration, we simulate growth, carbon stocks, biodiversity, and management with harvest volumes over the next 200 years for a set of plots that represent a range of site indexes and tree species composition common in Norway. Using current prices of wood and costs of forestry, we find how the optimal management changes with browsing damages, with impacts on timber production, economic returns, carbon sequestration and biodiversity.

Session 12.1 Mapping disturbance agents

12.1.1

Using high-resolution satellite stereo imagery for mapping boreal forest fire fuel loads

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Abstract

Fires are an important abiotic risk factor for boreal forests. Moreover, it is projected that the associated risks would increase considerably in the future, as a consequence of a warming climate. This motivates the need to develop methods to estimate fire-related canopy fuel parameters (e.g., crown biomass and crown height) over large boreal forested areas. The developed methods should be applicable for remote but fire prone boreal areas, where auxiliary data such as from airborne laser scanning (ALS) may not be available. The aim of this study is to evaluate the suitability of very high resolution satellite stereo-imagery data for this purpose. In this work, we examined the efficacy of ALS-independent metrics; i.e., metrics that can be generated in remote boreal areas without ALS data. This is by either using a global DEM (such as the SRTM-based DEM) or by formulating metrics independent of DEMs. Our study area was centred around the Hiidenportti national park, in central Finland, dominated by natural forests. We acquired stereo imagery from the WorldView-3 (WV3) satellite, which has a ground sampling distance 50 cm. The images were acquired in the summer of 2021. We then generated photogrammetry-based digital surface model (DSM) from these images. The corresponding ground reference was a field dataset consisting of measurements from 36 forested plots. We then calculated several parameters plot-level parameters related to fuel load such as crown biomass, canopy height and timber volume. We also generated several plot-level metrics from the DSM. Our initial analysis of the correspondence between the WV3 DSM-based metrics and the field data are promising. For example, a ~52% correlation was observed between foliage biomass and a few Gray-Level Co-Occurrence Matrix (GLCM) metrics related to image texture. Our results suggests that generation and updating of wall-to-wall fuel load maps based on high-resolution satellite images holds promise.

12.1.2

Future Arctic (Wild)Fires

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Abstract

Wildland fires in the boreal and Arctic are increasing in frequency and severity, with extreme fire seasons documented across the Pan-Arctic and boreal in five of the last seven years – including an early start to extreme fires in 2023. Human-caused and wildland fires above 60°N were larger sources of black carbon and methane than current modeled estimates of anthropogenic sectors like energy extraction and transportation. Further, these large boreal and Arctic fires have the potential to release large amounts of carbon dioxide and subsequent methane emissions from degraded permafrost and peat fires, as well as negatively impacting air quality thousands of miles south. By end of this century, current extreme fire years in the Arctic will likely be a normal fire year for much of Greenland, North America, Northern Europe, and Eurasia. As a new horizon in global wildland fire science, novel scientific pathways must be undertaken to improve our understanding and management of wildfires in the High Northern Latitudes – including understanding how NASA and U.S. researchers can enhance collaboration and develop near-real-time fire and smoke monitoring and modeling between North American and European ecology, fire, and climate scientists and stakeholders. Issues of inclusion, diversity, and equity are inherent to understanding fire ecology, impacts, and management in the Arctic and boreal, including centering and deferring to Indigenous and local communities when constructing best management practices.

12.1.3

Mapping wind vulnerability in Norwegian forests under selected management scenarios with ForestGales

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Abstract

In Europe, more than half of all the damages to forest by volume results from windstorms. In Norway, forests cover more than a third of the country's land surface, and are important economically, culturally, and socially. Storm damage can have a range of consequences for the forestry industry and society including dangerous forest operations, reduced wood quality, reduced timber prices, electric outages, and increased risk for bark beetle outbreaks. It is therefore crucial to understand the risk for wind damage across the Norwegian forests under current conditions but also for a range of climate and management scenarios for the future. We assessed the fine-scale risk of wind damage over the entire country and inspected how changes in forest management strategies may modify the risk over time and space in Norway. We used the Norwegian forest resource map SR16 which contains detailed information relative to tree species, height, volume, and biomass and has been used in large-scale analyses of the forest resources in the country. We applied the ForestGales model to predict critical wind speeds for damage for individual forest pixels and stands in the SR16 map. Testing of the model results is complex at this scale, nonetheless we present how well the identified risk regions correspond to reports of wind damage in recent history. Further, we evaluated how the risk of wind damage may shift in time and over the landscape with different management strategies. These results will be further used in integrated assessment of risks in the Norwegian forests under current and future climatic and management scenarios to provide information on how to change our management practices to develop climate-smart forestry in Norway and improve the forest's resiliency.

12.1.4

Mapping the stand-level risk of spruce root rot in Finland using harvester data

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Abstract

Root rot is a major problem in Norway spruce forests in southern Finland, leading to reduced timber quality, growth losses, control costs and increased mortality. While traditional methods for mapping root rot have been slow and laborious, harvester data provides a promising source of information for improving the current level of knowledge on the root rot situation. Here, we used harvester data to map the risk of root rot in spruce stands in Finland. To do this, we first built a statistical model predicting the percentage of stems affected by root rot. For the training of the model, we used an extensive set of harvester data, where presence of root rot was determined on stem-level, by an algorithm based on stem-specific cutting information from harvesters. The data set contained over 9 000 clear-cut Norway spruce stands in southern and central Finland. The model consisted of two parts, a fixed component describing the effects of different stand-specific drivers on root rot, and a random component designed to describe the spatial patterns in rot occurrence. The fixed part included variables describing forest stand attributes, soil and climate conditions, and proxies for the past forest management intensity. The model was then used to map root rot risk, by predicting the probability of root rot using spatial data sets of the variables in the fixed part of the model, and the known locations of root rot infected stands in the harvester data set for the random part of the model. The results quantify the relationships between root rot and the different predictors and improve the current understanding on spatial distribution of root rot infected stands. This information can be used to support forest management decisions aiming to control the spread of the root rot causing fungi and to eradicate it from the currently infected areas.

12.1.5

Wind damage detection in Nordic forests by 3D reconstruction of very high resolution optical satellite imagery

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Abstract

Wind is a major natural disturbance agent in European boreal forests, and climate change is expected to make windthrow damage a more frequent occurrence. Very high resolution (VHR, pixel size <1 m) optical satellite imagery, available since the late 1990s, is a valuable source of spectral information on forest health and, when collected in the stereo mode, can be used to extract height information and build accurate canopy height models (CHMs). For this study, we chose a severe windstorm event that caused extensive windthrow (2 million m^3) in conifer forests in south-eastern Norway in November 2021 to test whether windthrow can be reliably detected by photogrammetric 3D reconstruction of a post-storm stereo pair collected by the WorldView-3 satellite (pixel size 0.3 m). We derived a difference CHM by comparing the post-storm photogrammetric CHM with a LiDAR CHM collected in 2017 and trained two windthrow classifier models: (1) a simple thresholding model using canopy height change between the pre- and post-storm CHMs as the sole predictor and (2) a logit model adding pre-storm basal area (BA) as an explanatory variable. We found that adding BA failed to improve the windthrow classification accuracy and that using the simpler thresholding model, highly accurate windthrow maps of denser forest stands (BA >15 m^2/ha) can be produced with a sensitivity over 96%, specificity over 71%, and the Matthews correlation coefficient (MCC) over 0.7. Windthrow detection in sparse forests was found to be unreliable. The effect of imperfections in the ground reference data on model accuracy assessment was examined. Despite the collection challenges associated with the low sun elevation during the late autumn and winter period, VHR stereo satellite imagery is a viable source of forest canopy height information that is sufficiently accurate to map forest disturbances involving canopy height loss.

Session 12.2 Technological solutions and innovations

12.2.1

Identifying potential locations for bilberry picking with remote sensing, in-situ field data and phone-application

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Abstract

The aim of the study was to create a practical method for identifying potential berry yield locations in the forest landscape with help of remote sensing, in-situ field data and phone-application for supporting the development of the local berry value chain. In 2021 we collected local training data of 503 field plots from a study area of circa 25 x 45 km in Västerbotten, Sweden. The potential for bilberry production was evaluated by measuring the shrub cover and amount of raw berries. Remote sensing data from the study area included a Sentinel 2 image from same summer, airborne laser scanning data from 2020 and other map products. We created classification models for bilberry shrub and yield using both logistic regression (2 classes) and ordinal regression (3 classes). Tested predictor variables included: spectral metrics from satellite data; structural metrics from laser data; existing maps of tree species, stand attributes, site-index, soil moisture and land use classes. The 2-class models performed better than three class models, delivering the AUC 0.73, overall accuracy 0.83 and kappa value 0.51 for best bilberry shrub model and 0.75, 0.77 and 0.50 respectively for best bilberry yield model. The metrics used in the best models included both laser based and spectral metrics but also e.g. volume of pine, soil moisture and site-index for pine were used. Raster maps were produced over the study area and validation data of 525 plots were collected in summer 2022. The AUC, OA, and kappa-values in validation data where similar to training data for bilberry yield (0.73, 0.74 and 0.46), but lower for bilberry shrub (0.61, 0.68 and 0.24). A dedicated phone-application was develop during the project, which was used both for collecting the field data and for presenting the potential locations of berry yields in a map to support local berry value chain.

12.2.2

Using a location-based game for forest planning purposes

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Abstract

When it comes to forest planning and design, it is important to gather information about the emotions and expectations of forest users. People attach meanings to areas based on memories, emotions, knowledge, and preferences. Different people, therefore, have different and often contradictory hopes and expectations about how these areas are used and managed. In order to realize a forest's full potential, these various opinions should be taken into consideration. This would allow for a balanced consideration of different planning scenarios with greater social acceptability. Location-based games and gamified motivational information systems have been transforming the way the public interacts with forests and can be harnessed to gather this kind of data in new ways.

In this study we use the location-based game, Geocaching, to bring players to five specific areas within peri-urban forests and national parks in Eastern and Western Finland. Through surveys embedded within the game, we gauge players' opinions about the surrounding forest.

In our presentation, we will explain how these trails were created in close collaboration with the Finnish Geocaching community. We will provide some preliminary notes on the experimental design and how effective the surveys have been in capturing the meanings people attach to these forests as well as their landscape preferences.

12.2.3

Development and assessment of a system for digitalized follow-up of nature and culture conservation measures at harvesting using harvester data

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Abstract

Nature and culture conservation measures are important elements in planning and performing sustainable forestry activities. Measures are normally followed up based on a limited sample with a delay in relation to the time of harvesting. A switch to using existing digital information for follow-up thus has potential to broaden and accelerate follow-up and documentation of most of the conservation measures implemented in thinning and final felling.

Together with forest companies, Skogforsk recently defined performance indicators that could be generated in a digital system for conservation follow-up. The indicators have subsequently been integrated into a model that enables follow-up of high stumps, stumps in cultural environments, retention trees, and smaller and larger clumps of trees, such as edge zones and habitats requiring conservation. The model has been implemented into software, and results have been assessed based on manual reference measurements.

Input data to the model developed in the study comprises production data from harvesters and registered stem codes, harvest plans, and geodata, including basic forest attribute data, and information from the Swedish national road database (NVDB). The regulatory framework for the FSC standard has been incorporated, to enable presentation of performance indicators in relation to the forestry certification systems.

The model was assessed based on data from 13 final-felling sites in five areas spread over Sweden. Coordinates of felled and retained forest areas as well as the number of remaining trees were manually recorded. Comparison of the results generated by the model and the manual reference measurements showed that the algorithm for area estimated both larger felled areas and small remaining areas with high precision. However, there was a slight tendency for the algorithm to overestimate the felled area. The model was shown to estimate the number of remaining trees per hectare with negligible systematic deviation and high precision.

12.2.4

Predicting spatial and temporal variation in forest trafficability: Training a machine learning model against harvester-measured rolling resistance

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Abstract

Mechanized forest harvesting operations with heavy machinery can lead to significant soil rutting. To ensure environmentally acceptable and efficient forest operations, reliable knowledge on trafficability and soil strength is needed. Factors influencing soil strength, such as soil texture, soil moisture, organic matter and clay content, bulk density, stoniness, and root system, have considerable spatial and also some temporal variability. While rather accurate spatial data on topography and above ground vegetation are available, the factors influencing soil bearing capacity have coarse data resolution and collection of detailed data is slow and expensive with traditional methods. We propose that utilizing the CAN-channel data from harvesters operating in the forest can provide a proxy for trafficability by informing about soil bearing capacity, and thus, help in developing trafficability prediction. There are already several mapping approaches available serving forest trafficability assessment, but the accuracy and particularly the temporal aspects require more development. More detailed understanding of the temporal variation in trafficability is crucial particularly due to climate change that might change the duration and timing of frost periods when trafficability is on sufficient level. In our Academy of Finland funded project ("TRAM"), we calculate the rolling resistance based on CAN-channel data on engine power used for moving the harvester in the forest. We characterize and interpret the rolling resistance variability in typical forest landscape in Southern Finland. We further explore how accurately rolling resistance can be predicted with a machine-learning model from open spatial data and hydrological state of the landscape modelled with a distributed forest hydrology model SpaFHy. We have extensive data from 11 sites in Southern Finland collected during spring and summer of 2021, which enables including the temporal variation required for developing dynamic trafficability maps.

12.2.5

Estimating the accuracy of smartphone app-based removals against actual wood harvesting data from clear cuttings

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Abstract

Trestima is a machine vision-based smartphone application that utilizes the classic relascope theory to obtain estimates of forest resource attributes from smartphone photographs. The aim of this study was to investigate the accuracy of Trestima estimation by means of roundwood volume estimation and evaluate if it is accurate enough for operational forestry. Our data consisted of 37 stands covering of an area of 76 hectares. where Trestima estimates were obtained by forestry professionals in an operational context. The results were compared with harvester data from clear cuttings located in southeastern Finland. The number of photographs taken per stand was 1–29 with an average of 7.3. Industrial roundwood volume harvested from the stands was altogether 21,531 m^3 and average harvesting removal per hectare was 282 m^3. The overall Root Mean Square Error (RMSE%) of Trestima estimation was 27.7 which is comparable to traditional relascope field assessments. The accuracy of Trestima estimation was fairly good when there were ten or more pictures per stand. In this case, RMSE of roundwood volume was 17.7%. If the number of pictures was smaller than ten, the accuracy of Trestima was weaker (RMSE% 22.7–55.3). On average, Trestima underestimated the harvested volumes slightly in Scots pine (*Pinus sylvestris* L.) stands (Bias% 11.4–89.2). With Norway spruce (*Picea abies* (L.) Karst.) stands, the bias was smaller (Bias% -12.7–12.4). In an operational context, the lack of pictures resulted in weak accuracy in Trestima-based estimation of forest stand attributes. With the adequate number of pictures, the Trestima smartphone application is a possible option for traditional field measurements.

Special session 13.1 Remote sensing of northern peatland

13.1.2

Novel site type, nutrient-level and land use database of peatlands in Finland

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Abstract

The main objective of this research was to produce a novel high-spatial-resolution country-wide peatland GIS database to provide up-to-date information for greenhouse gas emission inventory and mapping of threatened site types. The open-source raster database was published in early 2023 including peatland site types, their nutrient levels, and current land use classes including state of forestry drainage, active and abandoned agricultural fields on organic soils, and land cover of peat production areas. The work was accomplished using remote sensing data of optical and SAR satellites, airborne laser scanning, low-altitude airborne geophysical surveys and multi-source forest inventory GIS datasets. The peatlands were classified with the random forest classifier after feature selection with a genetic algorithm using ground truth data on three pilot areas. The country was divided into five combined peatland vegetation zones for machine learning runs. Challenges were faced especially in classification of 39 forestry drained peatland site types overall accuracies ranging 29.3–56.6%. Accuracies increased to 39.7–66.5% when the drained site types were reclassified to 5 nutrient level classes (+ 3 land use classes) useful for greenhouse gas inventory. The respective overall accuracies for undrained site types were 32–49.3% and for nutrient level classes 46.6–66.5%. Treeless or sparsely forested peatlands and the land use classes were moderately well classified. Land cover classification of the peat extraction areas to peat, vegetation, forest and water covered classes was highly successful with 86.9% producer's and 89.1% user's accuracies. Further research is required to evaluate the applicability for greenhouse gas emission inventory. The improved version of the database could utilize the most recent airborne laser scanning data and high resolution satellite datasets. The work was accomplished in Advances in soil information – MaaTi - project (2021-2022) funded by the Ministry of Agriculture and Forestry of Finland Catch the carbon programme.

13.1.3

Quantifying wetness variation and drought-sensitivity of pristine aapa mires with Sentinel-2

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Abstract

Aapa mires are northern peatland ecosystems characterized by fen vegetation and waterfilled depressions ('flarks') that provide a unique habitat for multiple red-listed species but are also a significant natural source of methane. Ecological and biogeochemical processes in flarks are closely tied to hydrology and are sensitive to changes in water availability caused by climate change and human activity, such as ditching in surrounding landscape. These stressors have already triggered fen-to-bog transition in aapa mire flarks, leading to shrinkage of flark area. Here, we utilize Sentinel-2 satellite data in a cloud-based approach to semi-automatically retrieve regional and national scale information of wetness variability and drought-sensitivity of flarks. A surface moisture index together with automated detection of water-saturated surfaces in 20-meter pixels is used to quantify monthly wetness variability during 2017-2020 in over two thousand pristine mires. The results revealed sensitivity to climatic variation and dramatic impacts of 2018 drought summer, particularly in southern parts of aapa mire occurrence zone. Of flark surfaces that on climatically normal years maintained wet conditions throughout summer season, over half dried (58%) during the summer 2018 in the southern regions. Generally, on average almost one third (28%) of usually wet surfaces experienced drying in mires. Moisture index values in late summer were on average 36% lower than in normal years, and in south 52% lower. Wetness-responses varied largely between sites, implicating significant role of environmental factors in drought-sensitivity. Further analysis is needed to link sensitivity to potential drivers, including ditching intensity in landscape. This study provides the first comprehensive national level assessment and spatially explicit data of seasonal and annual wetness variability and drought-sensitivity of pristine aapa mires, which is crucial information for effective conservation and restoration planning, and useful in upscaling efforts of carbon exchange in peatland ecosystems.

13.1.4

Detecting spatio-temporal patterns of wetness in restored peatlands with multi-scale remote sensing

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Abstract

Peatland restoration aims to bring back the original peatland ecosystem functioning. A key measure of successful restoration is the change in peatland wetness and hydrology. Changes in hydrology are typically monitored with point-based observations, while the use of remote sensing, capable of spatially extensive and temporally dense detection, has been rare. To address this gap, we assessed how well spatial and temporal patterns of wetness can be tracked with satellite and drone remote sensing approaches.

Our study areas were five mire sites undergoing hydrological restoration located in the Finnish aapa mire region. We monitored the changes in wetness with manual and automatic water table level (WTL) measurements during two growing seasons and utilized satellite (Sentinel-2, Landsat, PlanetScope) and thermal and multispectral drone imagery. We tested the functionality of different optical and thermal spectral indices and models and topography-based metrics.

Satellite-based optical indices tracked temporal changes in WTL with reasonable accuracy but there were differences between sites which indices functioned most accurately. Fine-scale spatial variability in WTL could be detected with drone-based optical and thermal approaches especially during early growing season but less accurately during peak-growing season when dense vegetation was hampering the monitoring. Topography-based hydrological indices functioned worse than optical and thermal approaches in WTL detection. Changes in surface elevation caused by restoration and hydrological conditions could be monitored with digital elevation models quantified from precision (RTK/PPK) drone positioning.

Our results indicate that satellite and drone remote sensing has potential for monitoring hydrological impacts of peatland restoration but due to site-specificity in model performance and time-specificity in drone data usability, the monitoring approach should be carefully planned and tested.

13.1.5

Spectral properties of dominant Sphagnum moss species in boreal peatlands

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Abstract

Boreal peatlands store up to 25% of global soil organic carbon and host many endangered species; however, they are facing degradation due to climate change and draining. In boreal peatlands, vegetation indicates the ecohydrology and health of this ecosystem. Therefore, applying satellite-based remote sensing would enable spatially and temporally continuous monitoring of the changes happening in peatland vegetation and, correspondingly, the whole ecosystem. New multi- and hyperspectral satellite data offer promising approaches for understanding the spectral properties of peatland vegetation at high temporal and spectral resolutions.

One of the most dominant features of peatland vegetation is the genus Sphagnum moss species. For this study, we sampled eight common Sphagnum species. After that, we measured the species' nadir-view reflectance spectra (350–2 500 nm) in a dark laboratory with a spectroradiometer four times throughout one week, together with their mass. Further, we examined (i) their inter- and intraspecific spectral differences throughout the experiment and (ii) whether the species or their respective habitats could be identified based on their spectral signatures in varying states of drying. First, we showed that spectral variation in the shortwave infrared (SWIR) region from 1 100-1 300 nm is highly explainable by the species. Second, we observed that wavelength regions in SWIR region from 1 100 nm to 2 500 nm were the most informative for detecting moisture. Overall, the findings of this study suggest that the most informative spectral regions to retrieve information about the Sphagnum species and their state of desiccation are in the SWIR region.

Session 13.2 Carbon dynamics and mitigation

13.2.1

Untapped Afforestation and Reforestation Potentials for Climate Mitigation in the Boreal Zone and Beyond

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Abstract

This study aims at identifying the untapped climate change mitigation potentials that can be achieved by large-scale and multi-purpose afforestation/reforestation with special emphasis on the boreal zone. While at global levels afforestation, reforestation, and restoration of (abandoned) agricultural land generates a large potential for carbon sequestration in the boral forest increasingly more area is exposed to severe and often stand-devastating wildland fires which could benefit from immediate reforestation.

A combined remote sensing/GIS approach coupled with biophysical forest and forest fire modeling has been applied to identify potential afforestation locations and to estimate the associated land-based CO_2 sink. Three possible scenarios have been identified including I) afforestation; II) Reforestation; and III) technological Carbon Dioxide Removal (CDR) options (i.e., Bioenergy combined with Carbon Capture and Storage, BECCS). In all scenarios, utmost priority is given to sustainable forest management and nature/biodiversity conservation. Forest modeling results have been combined with recent data sets

Global results indicate a total potential afforestation area of 1.45 billion ha with a carbon sequestration/CDR potential of 3.35 billion tC/yr. While the tropics are the region with the largest productivity per hectare, The largest area available for afforestation belongs to the USA. With respect to reforestation activities after wild land fires, assisted reforestation or restoration of a forest at a one-year burnt area would enable global carbon sequestration in the dimension of 258.8 million tC/yr. This reforestation would not only result in potential negative emissions but comes along with multiple co-benefits including accelerated revegetation and accelerated reaching of higher productivity levels. In addition to presenting latest global and boreal figures on each scenario, the study results underline the importance to combine afforestation and restoration efforts with intensive conservation as well as sustainable forest management efforts.

13.2.2

A novel framework for assessing GHG mitigation and nature restoration policies in forestry under climate change

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Abstract

EU adopted an ambitious target of 55% reduction of net greenhouse gas emissions (GHG) by 2030, compared to 1990 levels, including a net LULUCF sink of 310 $MtCO_2eq$ mostly in the forestry sector. However, GHG mitigation in the land use sector interferes with other important spheres like food security, fiber and energy supply, and biodiversity protection. Climate change adds yet another dimension of risks and opportunities to the forestry sector by modifying growth conditions and disturbance regimes. Policies designed to reduce GHG emissions should take into account these complex interdependencies in a systemic manner, as well as potential leakage of emissions to other sectors and regions. For this purpose, we propose a novel modeling toolbox uniting a number of models and datasets. We use the process-based model 3PGmix informed with CMIP6 climate data for representative concentration pathways and respective increases in atmospheric CO_2 concentrations for projecting future forest growth. To estimate forest damaged by wind, fire, and insects we combine the information from the studies on the disturbances by Seidl et al. (2014) and Forzieri et al. (2021) downscaled using the vulnerability models (Forzieri et al. 2021). We apply the GLOBIOM land use model for projecting demand for harvested wood products and bioenergy subject to scenarios of socioeconomic developments and specific policies and trade flows, taking into account also the agricultural sector and the link to food security. We apply the Global Forest Model (G4M) for assessing the effects of forest management and woody biomass harvesting on greenhouse gas emissions from forests under a series of scenarios. In G4M, we implement the forest growth shifts from 3PGmix, the estimated forest damaged due to disturbances, and wood demand derived from GLOBIOM. A map of primary and old-growth forests has also been incorporated into G4M for consideration of nature conservation options.

13.2.3

Is current science able to reliably assess uncertainties of the budget of climatically active substances (CO_2, CH_4, N_2O) of Russian forests?

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Abstract

Recent peer-reviewed research results, as well as national communications of Russia to international climate change bodies on Net Ecosystem Account of climatically active substances (CAS) of forest ecosystems are very diverse. The most uncertain are the estimates given by the bottom-up empirical approaches (diverse inventories, methodology recommended by IPCC, landscape-ecosystem approach): if we exclude the evident outliers, the published estimates of carbon sink for period 2000–2019 are in range of 200 to 800 Tg C yr^{-1}. The results of atmospheric inverse modeling, and most of applications of Dynamic Vegetation Models, are less diverse, but on average they provide the estimates of the sink less than the bottom-up approach. In essence, estimating the budget of CAS of forest ecosystem belongs to a special class of under-specified systems, for which defining the "full uncertainty" (including its structural part) requires application of different methods of the accounting for with following mutual constraints of the results and their uncertainties using the Bayesian method.

This paper attempts to analyze sources of uncertainties of basic bottom-up and top-down methods of CAS estimation in connection to specifics of Russian forests, and with a special emphases to 1) compatibility of definitions used by different methods; 2) reliability of information sources; 3) completeness of consideration of regional specific of northern territories in the global products and models; some others. It is shown that following the principles of applied systems analyses for empirical bottom-up methods would allow to decrease the diversity of results substantially. However, there are a number of limitations in mutual constraints of the final results. Estimating the carbon sink of the forest at national scale based on available data is subject to random and systematic errors, and error propagation to the uncertainty and bias of the country total still requires more effort and better data coverage.

13.2.4

Improved forest management for increased carbon sequestration: an assessment of the most prominent approaches in Norway

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Abstract

Intensification of forest management is seen as one important measure to increase carbon sequestration and contribute to balance CO_2 emissions and mitigate climate change. Potential measures for forest management intensification include intensified regeneration after harvesting, increased planting density, use of genetically improved material, nitrogen fertilization, and pre-commercial thinning. Here we simulated the mitigation potential of these practices in Norwegian forests during the 21st century (2020–2100) using data from the Norwegian National Forest Inventory. The accumulated carbon dioxide removal potential of intensifying all the proposed measures in one scenario was estimated to be around 307.8 Tg CO_2 by 2100, corresponding to offset more than six times Norway's total GHG emissions in 2019. Intensifying pre-commercial thinning gave the largest additional carbon dioxide removal during the simulation period when these measures were considered separately.

13.2.5

The effects of forest operations and silvicultural treatments on litter decomposition rate: a meta-analysis

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Abstract

Litter decomposition is one of the most important ecological processes in the forest ecosystems. Notwithstanding a great interest towards understanding the drivers of litter decomposition rate in forest ecosystems, scientific literature still lacks of a comprehensive review that summarises the effects of soil disturbance related to forest operations and to the various silvicultural treatments. To fulfill this knowledge gap we developed a global meta-analysis investigating the effects of active forest management on litter decomposition rate. We further applied sub-group meta-analysis as well as mixed effects meta-regression to investigate the influence on litter decompositon of categorial (kind of stands and kind of substrate used for decomposition experiments) and continuous (average temperature, average rainfall, used mesh size and biomass percentage removal) moderators. Hedges' g was applied as measure of effect size. The main results are still under elaboration but a preliminary clear output consists of the low number of studies dealing with the influence of forest operations on litter decomposition. On the other hand, studies dealing with the consequences of silvicultural treatments are much more but they show a great variability among them. Further research is needed in the topic but, hopefully, the results of such a comprehensive studies would be helpful to summarise the state of the art and to indicate the directions for future research.

13.2.6

Improving the understanding of boreal forest carbon cycle dynamics using a model-data fusion approach

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Abstract

The boreal zone has historically acted as a carbon sink, however, these approximations are highly uncertain. There is an urgent need to better understand current and future carbon cycle dynamics in this biome and to reduce the uncertainties associated with sink-source projections.

Model-data fusion allows for the explicit quantification of these uncertainties while simultaneously permitting the exploration of various plant-carbon-climate interaction scenarios. Here, we employed the use of the Data Assimilation Linked Ecosystem Carbon cycle model (DALEC) embedded in the CARbon DAta MOdel fraMework (CARDAMOM). CARDAMOM takes a Bayesian approach to calibrate ecologically relevant model parameters (i.e. trait values) at each pixel or site location independently. This dynamic calibration technique allows for the investigation of plant trait variation across space, potentially improving our understanding of the underlying controls on the carbon cycle throughout the Fennsoscandian region.

During this process, we found that widely used satellite-based leaf area index (LAI) products show unrealistic seasonal behavior at the high northern latitudes given the predominance of evergreen needleleaf species. Assimilating these observations of satellite-based LAI into CARDAMOM had significant implications on model outputs, exhibited at the site-level across various locations in Sweden and Finland. We therefore developed a method that constrains the prior probability distributions of key leaf trait parameters. This was done by leveraging information from previous studies on the spatial patterns of species-specific needle lifespans and data from Sweden and Finland's multi-source national forest inventories.

Data-driven constraints on key leaf traits, coupled with the assimilation of summer-only LAI, improved model performance at the site-level when compared against eddy covariance-based net ecosystem exchange and its derived component fluxes of gross primary productivity and total ecosystem respiration. This method is currently being tested at a regional scale and may allow for improved understanding of carbon flux dynamics in the Fennoscandian boreal zone.

Session 14.1 Remote sensing

14.1.1

Calibrating model-based predictions of forest characteristics based on remotely sensed data

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Abstract

Predictions of forest characteristics based on remotely sensed data are increasingly being applied to support forest management and environmental monitoring. A typical feature of such predictions is that they are obtained from predictors that are approximately unbiased conditional on the input data. That is, given the remotely sensed data for individual pixels or aggregations of pixels, such as forest stands, the predictions coincide with the true value on average across a large number of randomly selected pixels. The predictors may be based on models estimated using traditional regression analysis, but increasingly various other machine learning techniques are being applied for the purpose as well.

However, unbiased prediction conditional on the input remotely sensed data does not imply that predictions for specific individual pixels or stands are unbiased. On the contrary, from this point of view the predictions are typically biased. If a specific stand is selected and studied, we cannot expect the average value of the predictions to coincide with the true value across a large number of predictions. Predictions are normally shrunk towards the mean value of the model training dataset, which means that large true values typically are underestimated and small true values overestimated. The magnitude of this effect depends on the strength of the correlation between the remotely sensed data and the characteristic being predicted. Applying a dataset with such predictions in forest management or environmental monitoring will cause problems in several applications.

In this presentation different methods to handle this problem will be described. They range from various calibration techniques to simulating residual error terms to model-based predictions to re-establish the full range of "real" values. The usefulness of the techniques in different types of application will be discussed.

14.1.2

Hyperspectral measurements in mapping biodiversity of trees – evaluation based on in situ and laboratory observations

Aarne Hovi, Jussi Juola, Miina Rautiainen

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Abstract

Spectral reflectance characteristics of forests are determined by their biochemical and physical properties. These properties, in turn, can depend on species composition, environmental and site conditions, and possibly even on genetic variation within species. Thus, it has been argued that hyperspectral data can be used for mapping the biochemical and physical properties (functional diversity), species (taxonomic diversity), and genetic origin (phylogenetic diversity) of plants. Laboratory and in situ measurements are a valuable tool for developing the understanding of remote sensing observations. In this presentation, we use spectral libraries of tree foliage and stem bark that we have collected through in situ and laboratory measurements since year 2016. With these data, we evaluate to what extent the above mentioned three levels of biodiversity are possible to estimate from hyperspectral data of boreal tree species. We show that there are wavelength-dependent spectral differences between tree species, but also significant within-species spectral variation due to, e.g., local environmental conditions. On the other hand, our case studies show that geographical variation in tree foliage spectra is relatively small and that spectral differences do not always follow the phylogenetic differences. These findings may indicate that variation in local growing conditions, rather than genetic variation, is the most important driver of within-species spectral diversity of boreal trees. However, more research is recommended to generalize these findings related to trees, and to upscale them to canopy level. We also highlight the importance of careful measurements and unified measurement protocols, to ensure that observed spectral differences are due to the vegetation properties, i.e., are not artefacts caused by measurement conditions or varying measurement setups.

14.1.3

UAS-SfM-derived Terrain Models for Monitoring the Changed Flow Paths and Wetness in Minerotrophic Peatland Restoration

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Abstract

Most northern peatlands are severely degraded by land use and drainage. Peatland restoration is an effective way to promote biodiversity, return the natural functions of peatlands in the catchment hydrology and re-establish the long-term carbon sinks. The main aim of the restoration is to direct the water flows back to the pristine routes and to increase the water-table levels. Conventional monitoring methods such as stand-pipe wells are typically limited to sparse locations and cannot give a spatially representative overview.

We introduced a novel high-resolution approach to spatially evaluate the surface flow paths and wetness changes after peatland restoration. We applied a UAS SfM (Unmanned Aerial System Structure-from-Motion) method supported by ubiquitous LiDAR (Light Detection and Ranging) data to produce digital elevation models, flow accumulation maps and SWI (SAGA Wetness Index) models for two boreal, minerotrophic restoration sites and their pristine control sites. The pristine sites were to represent natural changes and technology-related uncertainty.

According to our results, the hydrological restoration succeeded at the sites showing that the wetness increased by 2.9–6.9% and its deviation decreased by 13–15% 1–10 months after the restoration. Absolute changes derived with data from simultaneous control flights at the pristine sites were 0.4–2.4% for wetness and 3.1–3.6% for the deviation. Also, restoration increased the total length of the main flow routes by 25–37% while the controlling absolute change was 3.1–8.1%.

The validity of the topography-derived wetness was tested with field-gathered samples which showed a statistically significant correlation (R2 = 0.26–0.42) for the restoration sites but not for the control sites. We conclude the water accumulation modelling based on topographical data potential for assessing the changed surface flows in peatland restoration monitoring. However, the uncertainties related to the heterogenic soil properties and complex groundwater interactions require further method development.

14.1.4

Modeling peatland site types and land use classes with machine learning and remote sensing

Jonne Pohjankukka[1], Andras Balazs[1], Timo Pitkänen[1], Janne Kivilompolo[2], Matti Laatikainen[2], Paavo Nevalainen[3], Sakari Tuominen[1], Jukka Heikkonen[3], Maarit Middleton[2]

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Abstract

This study focuses on the use of machine learning (ML) techniques for modeling peatland site types, nutrient-level classes and land use on three pilot areas in Finland. Peatlands provide a wide range of ecosystem services such as carbon sequestration and biodiversity conservation. However, the wide area mapping and monitoring of peatland areas is challenging due to their significant coverage and limited accessibility. By utilizing remote sensing (RS) data the monitoring of peatlands can be used to alleviate these challenges. In this research, we used different ML techniques, namely k-nearest neighbor, logistic regression, random forests, and multilayer perceptron, together with RS data for modeling peatland site type and land usage. RS data used in the study consisted of optical and SAR satellite remote sensing, airborne low altitude geophysical surveys, airborne laser scanning (ALS) and derived textural features, and multi-source forest inventory. Peatland field data for ground-truthing was provided from the databases of GTK and Luke. The optimization of used RS variables for modeling the peatland site types and land use classes was implemented using genetic algorithm feature selection. The results of the study show that the random forest algorithm outperformed consistently other ML methods in peatland site type classification (37-39 classes) with accuracy ranging from 36–41% across pilot areas. For higher hierarchical level nutrient-level classes, higher accuracies around 53–57% were acquired. In classification of peat extraction areas, logistic regression classifier performed most optimally with up to around 92% overall accuracy. In multiple experiments, the results of feature selection procedure highlighted the multi-source forest inventory, ALS derived and optical satellite feature variables to be the most important.
This work was accomplished in Advances in soil information – MaaTi - project (2021–2022) work package Remote sensing of peatlands funded by the Ministry of Agriculture and Forestry of Finland Catch the carbon programme.

14.1.5

Linking field observations to Sentinel-2 data to quantify peatland ground vegetation phenology

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Abstract

Peatlands are one of the largest terrestrial carbon pools and their vegetation acts as an interface to assess and quantify ecosystem functioning, and above ground biomass (AGB) and leaf area index (LAI) as well as their seasonality are generally used indicators in this. Although there are studies about field-based peatland vegetation phenology, there is not many studies how the vegetation seasonality varies among vegetation types (VTs) and plant functional types (PFTs), in particular how well these seasonal patterns can be detected by time-series of the satellite images. We carried out field inventories during vegetation growing season, from late May to October, across three boreal peatlands and forests in northern Finland. We linked the field-estimated AGB and LAI to Sentinel-2 (S2) time-series images via Random Forest (RF) regressions. Our results show that although ground vegetation AGB and LAI followed a clear unimodal curve over time in most VTs, their seasonal trajectories were relatively stable in forests and fen lawns. AGB peaked around the first week of August and in most cases, one to two week(s) later than LAI. Regarding PFTs, deciduous shrubs, forbs and graminoids presented clear unimodal seasonal patterns in AGB and LAI. In Sentinel-2 analyses, regressions for field layer vegetation were acceptable, showing the R2 24.2-50.2% (RMSE: 78.8-198.7 g m^{-2}) for AGB and 48.5-56.1% (RMSE: 0.207-0.497 m^2 m^{-2}) for LAI. Our findings suggest that S2 data allows, even with some limitations, tracing of the vegetation phenology within peatland-dominated ecosystems.

Session 14.2 Adapting to changing disturbances

14.2.1

Climate change and extreme events – modeling economic adaptation of forest enterprises through tree species selection at different spatial scales

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Abstract

Climate change and extreme weather events challenge the future productive potential of forest enterprises. Adaptation strategies are urgently needed. Here, we present methodological advances to explore:

which adaptation strategies maintain productive potentials of mountainous spruce stands;

how disturbances affect wood revenues;

at which spatial scale extreme events alter the optimal tree species composition.

To tackle these questions, we combined a set of mechanistic and empirical methods. First, we advanced a bioeconomic simulation-optimization model, based on Modern Portfolio Theory, to economically optimize tree-species portfolios at the stand level in the face of climate and market uncertainty (O1); using this model, we assessed four adaptation options: (i) adjusted tree species composition, (ii) mixed stands, (iii) shorter rotation periods, and (iv) bark beetle management. Second, we applied time series analyses to a real-world forest enterprise's harvest and sales records (O2). Applying the econometric results, we extended the simulation-optimization model to a forest enterprise (~230.000 ha) with multiple planning units (O3). We simulated the consequences of changing extreme-event patterns on the optimal tree species diversification under different spatial planning perspectives.

Our results suggest that proactively diversified tree species compositions are better suited to maintain productive potentials of spruce forests than reactive forest protection measures. Our econometric analysis suggests that losses in spruce revenues after disturbances were mainly due to oversupply on the wood market rather than lower wood quality. Our enterprise approach points towards the need of spatial models to account for extremes when selecting adaptation strategies.

Although our data sets were derived from Central Germany, the methods and considerations transfer well to boreal forests under climate change scenarios. We conclude that diversified species compositions in mixed stands are promising for buffering the economic consequences of climate change for forestry. In large enterprises, diversification across stands offers additional adaptation potential.

14.2.2

Impact of adaptation strategies on disturbance risk from spruce bark beetle and potential trade-offs with timber production

Teresa Fustel, Jeannette Eggers, Maartje Klapwijk, Tomas Lämås, Michelle Nordkvist, Karin Öhman

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Abstract

Spruce bark beetle (SBB) damage levels have increased in recent decades in Sweden. Forest management and global warming have jointly contributed to improve forest conditions required for the development of spruce bark beetle in northern latitudes. Also, forest disturbances such as wind fellings or drought contribute to increase the amount of breeding material in the forest to be used by this insect. Forest management is a tool that has large potential to change forest composition and structures to reduce susceptibility to damage by potential damaging agents such as SBB. In this study we developed and tested five management strategies that could potentially be applied in practice to reduce susceptibility to damage by SBB in the forest. The strategies were implemented in a forest decision support system where forest growth was simulated over a short planning horizon of 60 years and an optimization model was applied with the objective of reducing a SBB susceptibility index over time. In addition, a minimum harvest demand was included in the analyses to reflect closely current forestry practices.

14.2.3

Changing disturbance regimes and forest landscapes in Fennoscandia

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Abstract

Changing climate together with past and present land-use alter the structure and functioning of forests globally. In the boreal forests of Fennoscandia, intensive forest management has been the main disturbance agent over the past century influencing forest dynamics. However, natural disturbances are expected to increase with climate change. The aim of this study was to assess the effect of changing disturbance regimes on forest dynamics by examining pre- and post-disturbance changes in forest structure. The objectives were to compile a large dataset of National Forest Inventory (NFI) data from environmentally heterogeneous, but management-wise homogenous Fennoscandia (Finland, Sweden, Norway) and to analyze the recovery of structural complexity after disturbances and changes in the composition of disturbance agents present. The large NFI dataset covering over 30-years was sampled by overlaying the European Disturbance Maps (Senf and Seidl, 2021) and selecting plots with identified disturbance in the Landsat derived maps. The preliminary analysis with Finnish data resulted in total of 163 160 plots (34% of plots measured 1986–2020). The time between the disturbance event and the NFI-measurement was calculated for each plot. Preliminary results from the Finnish data indicated good recovery of stand basal area within 25 years (78% compared to mean before disturbance). Horizontal diversity, described with Gini coefficient, varied strongly but indicated a decrease after disturbance and recovery above the baseline within 25 years. A general trend in the composition of disturbance agents present was the dominance of fungi before disturbance, whereas the structural and compositional changes due to disturbance favored especially browsers. The results shed light on how forests respond to changing disturbance regimes and what is their recovery potential after major events.

14.2.4

The Last Tree Standing: Climate, stand and tree level effects on spruce survival during *Ips typographus* outbreak

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Abstract

Climate change intensified the frequency and severity of windfalls and insect outbreaks modifying large-scale forested areas and compromising forest ecosystem functioning. At the same time, natural disturbances serve as natural selection agents that facilitate forest adaptation to new environments. A minor proportion of resistant individuals that persist through herbivore pressure may accelerate adaptation via directional selection in favor of beneficial heritable traits. In this study, we investigated environmental, stand and tree level factors that influence Norway spruce (*Picea abies*) survival probability during prolonged stand replacing bark beetle *Ips typographus* outbreak in the Bohemian Forest. Our overarching hypothesis suggested that tree survival potential was shaped by performance trade-offs associated with limited internal resources. Energy and nutrient allocation strategies developed by trees over their life histories shape temporally and spatially sequenced chemical and mechanical processes that define tree resistance to herbivore. We used remotely sensed and field survey data collected over extensive forested area severely damaged by multi-year bark beetle outbreak at the border of Czechia, Germany and Austria. Non-linear logistic regression models were formulated to quantify tree level (crown and size) and environmental (climate and resource competition) effects on tree survival. We found that survival was a non-random process influenced by tree morphology, stand structure and climate conditions. Survival probability diminished in larger diameter trees. More extensive crowns increased tree survival chances presumably by more robust photosynthetic capability and greater carbon reserves. Amplifying climatic water deficit and pronounced resource competition escalated infestation probability. Sustained moisture deficit aggravated the negative effects of prolonged drought on tree physiological condition, compromising defenses of even smaller trees. Our results are in agreement with previous studies linking climate change to bark beetle proliferation. However, forest outcomes will depend on complex cross-scale interactions between stand structure, genetic diversity, phenotypic plasticity and climate trends.

14.2.5

The impact of bark beetle outbreaks on forest soil carbon accumulation

Hyungwoo Lim[1], Nils Henriksson[1], Reimo Lutter[2], Scott Buckley[1], Harald Grip[1], Shun Hasegawa[1], Daniel Lussetti[1], Ruth Magh[3], Zsofia Stangl[1], Axel Steinhof[4], Tomas Lundmark[1]

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Abstract

Forests are at increasing risk of dieback due to pathogen outbreaks. Despite fertilization being a common practice in boreal productive forests, it is not known how the fertilization-induced gains in soil carbon accumulation would fare after such perturbations.

We examine the impact of bark beetle outbreak on soil carbon pools. To simulate bark beetle damage to forests, we employed a large-scale tree-girding (1 000 m^2). Among three pairs of unfertilized control and three pairs of fertilized plots, the girdling treatment was randomly assigned to one of each pair, comprising a combination of girdling and fertilization treatments (n=3). Girdling was commenced in June 2002, resulting in the actual outbreak of bark beetles and death of all trees within two years.

Two decades after the treatment, soil carbon pool in girdled-unfertilized plots was 15.9±3.9 Mg C ha^{-1} lower than non-girdled plots, equivalent to 20 years' production of aboveground wood biomass of the studied forest. And the reduction occurred mostly from the stable mineral soil (0–40 cm). Fertilized plots, however, did not show reduction of soil carbon by girdling, due to a sustained carbon influx via understory vegetation turnover and reduced decomposition. Assessment of chemical and physical soil properties supports increased soil stability in the fertilized plots.

Our finding highlights the importance of soil fertility and vegetation dynamics in predicting ecosystem carbon dynamics in response to a disturbance.

14.2.6

Analysis of bark beetle communites in snow-damaged trees - are snow damages catalysts for insect damage or merely providing valuable dead wood?

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Abstract

Snow is the most common damage agent in Finland in terms of area affected by. Due to this, the Finnish Forest Damage Prevention Act mandates that excess amounts of damaged pine and spruce roundwood must be removed from the forest in order to prevent cascading bark beetle damage. Yet, the law makes no distinction between a tree fell by a wind in southern Finland or one cut by snow in the north.

More than million hectares of snow damage has been annually observed in the Finnish NFI, but large portions of these are old, meaning that the snow-damaged trees are not removed as the law mandates. This begs the question of whether snow damages are as serious catalysts for bark beetle damage as current legislation views, or whether they could be seen as easy sources for valuable dead wood?

We studied the diversity of insect communities occupying snow damaged spruce and pine trees. The measurements were carried out in Southern and Eastern Finland, in managed and protected forests, and they included fresh and old snow-damaged trees of various age and size.

Snow-damaged pines were most frequently occupied by Tomicus, Trypodendron and Pityogenes -beetles while spruces by Ips, Trypodendron and Pityogenes. Altogether, dozens of insect species were found from the snow-damaged trees. The severe damage-causing insects were not the clear dominant species, and even when they were, we could not detect signs of cascading insect damage in the neighbouring healthy trees. Based on our results, snow damages are not as severe sources for bark beetle damage as viewed in current legislation. Further, given how common snow damages are, their value for creating valuable dead wood in managed forests seems to be clear - and not as risky as thought.

7.3. Posters

P1.1

Will the increase of defoliating moth populations be a threat to boreal forests in warming climate?

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Abstract

As the climate is getting warmer, the northern edge of distribution of many species is moving towards higher latitudes. In North Europe, the northward movement of distribution range of defoliating moths *Lymantria monacha* and *Panolis flammea* has been very fast; since 1990 it has been approximately 300 km. Currently these species are not considered as serious forest pests in boreal forests yet. However, these periodically outbreaking defoliators of coniferous trees in Central Europe are capable of causing wide scale epidemics with serious economic damage. There are recent reports of new outbreaks in Estonia, Latvia, and Lithuania, which suggests that the distribution range and the outbreak zone of the moths are both moving northwards.

It is typical of the population density of defoliating moths to vary in cycles. In peak years, significant damage to trees can occur, sometimes leading to forest dieback. In pine forests of Germany and Latvia, pheromone trap monitoring programs have been developed with population risk levels predicting potential threat of severe defoliation by moths.

We intend to use Finnish pheromone trap data (starting from 2019) to examine how close Finnish populations of *L. monacha* and *P. flammea* are getting to damage risk levels seen in Germany or Latvia. This will be carried out by collecting three parallel trapping data sets from Finland (in 2021–2024) using German, Latvian and Finnish pheromone trapping systems. This allows us to calculate equations, which convert trap catches from one system comparable to data from another trapping system.

Moreover, by comparing pheromone trap data series from Finland, Germany and Latvia and connecting it to climate data from trapping sites, we can estimate the climatic conditions needed to develop outbreaks. This opens a way to model the effect of climate warming on future outbreak risk of defoliating moths in boreal forests of North Europe.

P1.2

Relationships between vegetation composition and rainwater, soil and groundwater chemistry in forested riparian zone

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Abstract

Environmental conditions in the riparian zone directly influence the aquatic ecosystem. Riparian vegetation plays a major role in nutrient leaching and maintaining biodiversity, but knowledge on the linkages between riparian vegetation and other environmental factors, though crucial for sustainable riparian buffer management, is still incomplete.

In seven 50 m long transects located in the riparian forest of different characteristics along a 1,4 km river section in the northern part of Latvia we studied the relationships between riparian vegetation, soil, groundwater and rainwater chemical composition. Transects were perpendicular to the river, to represent the distance gradient. Vegetation survey was performed in summer 2021 in 21 plots on each transect. Groundwater and rainwater samples in each transect were collected over a 12-month period, from December 2021 to November 2022. Additionally, in each transect litter, forest floor and soil samples were collected. Analyses of pH, electrical conductivity, total N, $N\text{-}NO_3^-$, $N\text{-}NH_4^+$, $P\text{-}PO_4^{3-}$, K+, Ca^{2+} and Mg^{2+} were done for the water samples, and analyses of total P, N and C, pH, C/N ratio and soil bulk density – for the soil samples.

Transects with predominantly deciduous trees had higher groundwater concentrations of total nitrogen and nitrates and higher rainwater concentrations of all nitrogen compounds and base cations. There was a tendency for transects with higher total nitrogen groundwater concentrations to be dominated by a greater number of nitrogen demanding species in the ground cover. At some soil layers, a positive correlation between total soil nitrogen and total groundwater nitrogen concentration was detected. Also, there was a positive correlation between the forest floor C/N ratio and the tree basal area of the plot's forest stand.

The study was performed within the frames of project "Implementation of River Basin Management Plans of Latvia towards good surface water status" (LIFE 18 IPE/LV/000014).

P1.3

Wind Damage Risk Assessment Tool (prototype) based on QGIS open-source platform

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Abstract

We introduce a tool for wind damage risk estimations based on open-source forest, terrain and climate data. The tool is implemented using QGIS open-source platform. We used terrain data from National Land Survey of Finland (NLS), forest data from Finnish Forest Centre (FFC) and wind climate data from Finnish Meteorological Institute (FMI). The tool predicts critical wind speeds (CWS) thresholds at the edges of clear-cut areas; wind speeds above this threshold results wind damage of trees (uprooting). CWS for wind damage was calculated using regression model based on mechanistic HWIND model calculations. Stand boundaries that were considered to have a potential risk of wind damage (at-risk edges) were searched for in the landscape. These were expected to be in stands with a dominant tree height >=16 m with at least 25% lower adjacent stand height along the upwind direction. CWS predictions were based on the characteristics of both the subject stand (tree species, mean tree height, and diameter/height ratio) and the adjacent stand (mean height and area of the stand). The CWS predictions were compared to the wind speed predicted for the target at-risk edges based on wind speeds at a nearby weather station. The wind speed at the target at-risk edge was calculated using information on the topography of the terrain and the roughness of the tree canopy in the upwind direction. The tool is still a prototype and needs improvements, e.g., user-friendly interface and visualization of wind damage risk through gamified approaches. We envision that the final version of the tool can be used in forest areas of boreal zone and beyond - where suitable stand data is available. In this presentation we demonstrate the performance of the prototype.

P1.4

Changes in forest fires in Fennoscandia from 1951 to 2100

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Abstract

Forest fires may benefit biodiversity, but can as well cause economic, social, and ecological damages. Understanding changes in the fire regimes in boreal forests is challenging due to the interaction between climate, biosphere and humans. Climate change affects the amount of the fuel for the forest fires both through changes in growth of the forest and decomposition of organic matter, as well as the properties of the fuel. We investigate changes in the fire regimes in Fennoscandia under two climate forcings, RCP 4.5 and RCP 8.5. Regional simulations with JSBACH-SPITFIRE model were done from 1951 to 2100 with 0.5˚resolution. Simulations were forced by down-scaled and bias corrected EURO-CORDEX data, derived from three global driver models (CanESM2, CNRM-CM5 and MIROC5). In the SPRITFIRE model, the probability that an ignition event will result in a spreading fire is described by the fire danger index, which depends on both the amount of fuel and the fuel moisture. The fuel moisture is a function of temperature and precipitation. Changes in fire regimes varies with location and scenario. Primarily due to the increase in temperature, the results from this study generally indicate drier fuel, greater probability for fires and longer fire seasons. This means that there will be more fires in the future.

P1.5

Extreme warming and drought decrease the photosynthetic activities of *Pinus densiflora* seedlings

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Abstract

Extreme climate events, such as warming and drought, are becoming increasingly common and are expected to induce a substantial impact on plant physiology. This study investigated the photosynthetic responses of 2-year-old *Pinus densiflora* seedlings during and after the extreme warming and drought treatments. The experiment was conducted in an open-field nursery using a factorial combination of two temperature levels (control and 87 days of +4 °C warming) and two precipitation levels (control and 33 days of 100% precipitation reduction). Photosynthetic activities were measured from May to October 2022. In June and July net photosynthesis rate, stomatal conductance, and transpiration rate decreased by 18.05%, 27.06%, and 27.18%, respectively, under the extreme warming treatment compared to those in the control. Similarly, in June net photosynthesis rate, stomatal conductance, and transpiration rate decreased by 22.17%, 29.67%, and 29.15%, respectively, under the drought treatment compared to those in the control. The interactions between the extreme warming treatment and the drought treatment were shown only in July. The results indicate that extreme warming and drought negatively impact the photosynthetic activities of *P. densiflora* Seedlings. This is likely due to the increased temperature and drought causing thermal and water stress for the plants, which induce stomatal closure and thereby decrease photosynthetic activities. This photosynthetic decline may ultimately reduce the growth and productivity of seedlings. Acknowledgments: This study was carried out with the support of OJEong Resilience Institute (OJERI) provided by National Research Foundation of Korea (NRF) grants and Korea Forest Service (KFS) as 「Graduate School specialized in Carbon Sink」.

P1.6

Impacts of biodiversity and carbon policies on Norway's forest management and timber production

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Abstract

It is of global importance to manage boreal forests sustainably as it is one of the largest biomes hosting the most coniferous forest area on the planet. Even-aged management with clearcutting is the dominant silvicultural regime in many Nordic countries including Norway. Policy makers and other decision-makers are seeking ways to increase carbon sequestration in forests. The public and scientific debate over the effects of silvicultural practices on ecosystem services such as biodiversity and forest carbon has intensified. Gaining new insights about the interactions between carbon, timber, and biodiversity goals, their trade-offs, and synergies will be crucial to developing effective policies. We assessed the effects of climate and biodiversity policies on national-level silvicultural practices, carbon fluxes, and the forest industry. We combined constraints on key forest biodiversity indicators and habitat support features with incremental carbon prices up to 1000 NOK/tCO_2eq. Following a two-step procedure, we first applied the tree-level simulator *TreeSim* to simulate management alternatives that mirror common management practices across Norwegian forests. Then, we applied the optimization model *NorFor* to compare management regimes, biodiversity levels, forest sector carbon fluxes, and timber and industry production over the next 100 years. Preliminary results showed trade-offs and synergies between carbon, timber, and biodiversity. Higher carbon prices with no biodiversity policy led to higher carbon fluxes and more intensive forest management. With a combined carbon and biodiversity policy, total timber harvest decreased on average by 12% compared to a business-as-usual scenario. With a biodiversity policy without carbon policy, forest management turned into less intensive with the area with no management increasing by about 60% compared to base levels. Finally, with a combined carbon and biodiversity scenario, forest management intensity was very similar to the base level, suggesting that the base scenario to a large extent supports the combined objectives.

P1.7

Relationship between forest stand and landscape variables and *Ips typographus* damages in Finland´s nationwide forest

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Abstract

Different insect pests are becoming more popular nowadays as they spread and increase in numbers due to climate change, as in the case of the European spruce bark beetle (*Ips typographus* =SBB), the most damaging insect pest to *Picea abies* trees in Central and Northern Europe. Its damages have been happening in Finland since the early 2010s, but limited research leaves knowledge gaps to propose effective forest management practices.

We wonder if SBB-damaged (SBBD) stands differ from *P. abies* stands in Finland, and do SBBD stands relate to landscape variables? We expect that SBBD and *P. abies* stands differ in terms of stand variables and that SBBD stands are related to landscape variables.

We compared SBBD and *P. abies* stands in terms of forest stand variables and studied the relationship between landscape variables and SBBD stands. We used forest-declaration-use and forest-stock data from the Finnish Forest Centre (Metsäkeskus) nationwide.

During 2012–2020, the total number of harvesting operations due to SBB damage was 4,691 and an epidemic phase during 2013–2016. We defined epidemic levels for Finland as >1,0 infestation/8000 stands or >1,0 infestations in 10.000 ha. SBB selected stands according to forest stand variables, overrepresenting herb-rich heath forest, mature stands and semi-coarse or coarse heath forest soil. In addition, older and bigger dbh stands were more prone to SBB damage. Shockingly and unlike foresters' expectations, dry soil stands were not particularly susceptible to SBB damage. We found a correlation between the number of SBB damages and distance to recent clear-cuts, previous year SBB damage and wind damages, showing more clear-cuts and previous year SBB damages around SBBD stands. We found that the epidemic phase could amplify the number of SBBD stands around clear-cuts. Implementing some forest management practices could make *P. abies* stand less prone to SBB damage.

P1.8

The role and possibilities of Finnish forest nature in the Finnish social and health service system

Kati Kiiski

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Abstract

There is some national and international research on the health and well-being effects of nature (e.g. Haahtela et al 2017, Tyrväinen et al 2018, Brondfzlo et al 2022). The effects have been shown to be mostly positive. Harnessing the health and well-being effects of Finnish forest nature as part of the Finnish field of social and health services and increasing the well-being of the population has not yet been implemented on a large scale. In Finland, there is a certified Green Care service system that ensures the quality of nature-based services, but it is not connected to social and health services. However, the concept of planetary well-being and planetary health has emerged in Finland recently. Intervention studies investigating the health and well-being effects of nature have been ongoing for ten years. With the help of these, the applicability of the services from the point of view of individuals (and certain customer groups) has been investigated, and the experiences of the target persons (customers) with nature-based services have also been studied. More research is still needed on this whole to assess how Finnish (forest) nature can be suitable as an effective part of the Finnish social and health service system. It is likely that the state of well-being of the population will continue to deteriorate in terms of both mental and physical functioning. Nature-based services are yet another little-used resource to potentially support social and health services and the population's well-being.

P1.9

Long-term management of forest land for increased climate change mitigation effect.

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Abstract

For the last decades policymakers and forest owners have been faced with difficult decisions on how to balance the provision of ecosystem services and economic benefits from forests, especially when the mitigation of climate change has become a topical issue. Responsible forestry practices can promote sustainable land management and biodiversity conservation. Additionally, after forest management practices harvested wood products (HWP) can be used as a renewable and carbon-neutral alternative to fossil fuels. We compared climate-change mitigation effect of different stand level long-term management strategies. We used data from managed mature (with long rotation cycles – 60 to 90 years, National forest inventory) and old-growth (182 years) stands to demonstrate the effect of forest management and retention (no management) on carbon stock in living tree biomass and HWP (after first and second rotation cycle) for four tree species: Norway spruce, birch, European aspen and Scots pine. Linear mixed effect model was used to evaluate differences in carbons stock between analyzed stands and species. Our data showed that carbon stock in old-growth forests was significantly higher than in mature stands, but long-rotation managed forests ensured substantially higher total climate change mitigation benefits (combined effect of carbon stock in forests and HWP). Tree species had a significant influence on carbon stock in HWP, showing higher carbon stock in deciduous trees. The notable part of positive carbon stock in HWP was the substitution effect which shows the potential reduction of greenhouse gas emissions coming of the replacement of non-wood-based equivalent products.

P1.10

Modelling carbon sequestration in stand and soil with varying forest management scenarios

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Abstract

As a part of Ministry of Agriculture and Forestry funded HIILIPOLKU project, modelling tools are coupled to provide decision support for forest owners on the linkages how forest management affects carbon sequestration in forest stand biomass and forest soil both for mineral and peatland sites. The study area, Lake Puruvesi catchment, is located in Southeastern Finland.

To provide extensive understanding on the effects of forest management, three scenarios with and without water protection emphasis were built from various management regimes (including e.g., longer rotation periods, continuous cover forestry, fertilization, increase of deciduous tree percentage) per each stand in the target area. Business-as-usual scenario is based on region's average logging amounts, carbon storage scenario aims at maximizing carbon storage, and biodiversity scenario emphasizes forest management regimes, where the proportions of deciduous trees and dead wood are higher. All scenarios are simulated with and without water protection emphasis, meaning potentially less ditch maintenance and/or fertilization.

Stand biomass carbon storage is calculated with Motti-simulations and for peatland stands SUSI-model is used to simulate the effect of ditch maintenance and fertilization. Soil carbon storage for mineral sites is calculated with YASSO-model and for peat soils SUSI-model is used. In Motti current climate data was used, whereas SUSI-model is additionally run with climate scenario data. The current carbon storage and change by 2050 are evaluated based on modeled results with consideration of effects on biodiversity and water protection and climate change.

Increasing the understanding of optimal forest management practices considering carbon sequestration as well as water and biodiversity protection is crucial for reaching the Carbon Neutral Finland 2035 goals. Running coupled simulation applications provides support for decision-making and increases understanding on the linkages between processes and management to reach practice-validated strategies for the implementation of best carbon sequestration methods in forest management.

P1.11

Water table dynamics detected with optical satellite data in northern peatlands

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Abstract

Peatlands are wetlands with a layer of partially decomposed plant remnants. Peatlands cover 3% of the global land area and store approximately 25% of the global soil carbon stock. The water table is one of the critical variables controlling peatland carbon exchange. Therefore, there is an urgent need for water table data at high spatial resolution. To address this need, we tested the applicability of the Optical TRApezoid Model (OPTRAM) to monitor the temporal fluctuations in water table over intact, restored (previously forestry-drained), and drained (under agriculture) northern peatlands in Finland, Estonia, Sweden, Canada, and the USA. We hypothesize that OPTRAM can indirectly depict the temporal changes in water table through remote sensing-based observations of the vegetation moisture status in peatlands. We tested our hypothesis using water table data from 2018 through 2021, across 53 northern peatland sites. Additionally, we calculated OPTRAM based on Sentinel-2 data with the Google Earth Engine cloud platform. First, we found that the choice of vegetation index as an indicator of vegetation greenness does not significantly affect OPTRAM performance in peatlands. Second, we revealed that the sensitivity of OPTRAM to water table dynamics in peatlands decreases over areas with high tree coverage. Finally, we demonstrated that the relationship between water table and OPTRAM often disappears for deep water tables. Overall, our results support the application of OPTRAM to monitor shallow to moderately deep water table dynamics in intact and restored northern peatlands that include spots with low tree cover density.

P1.12

ForestNavigator: navigating European forests and forest bioeconomy sustainably to EU climate neutrality

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Abstract

Boreal forests play a central role in the EU climate mitigation policy portfolio. Their contribution is expected to increase in the future as part of the part of the European Green Deal, where the EU has set the target of achieving climate neutrality by 2050, and of reducing its emissions by 55% by 2030. However, in the last decade, the rate of carbon removals from European forests has been declining, due to an increase in demand for wood, natural disturbances, and a growing share of forests reaching maturity. As a result, there is an increasing need for improved assessments of EU forests contribution to climate neutrality that considers the impacts of climate change and natural disturbances in a consistent way. In addition, such assessments need to also consider biodiversity conservation and other ecosystem services, to improve forest adaptation and resilience, as well as enhance synergies and mitigate trade-offs from the provision of wood products to the bioeconomy.

These challenges require a new generation of integrated forest modelling framework at the service of scientists and policy makers.

To address this need, the ForestNavigator Horizon EU project is developing a Europe-wide biophysical forest model calibrated to detailed regional forest models, specialized natural disturbance models, and the latest generation of earth system models. This new biophysical modeling tool will feed into a 'Policy Modeling Toolbox' including a new generation EU forest-bioeconomy integrated model (including consistent land use, biodiversity, economy, and climate modeling) and aligned with national forest policy models to compute robust pathways for European forests towards climate neutrality. This new generation integrated modeling framework is combined with near-real time harmonized forest data flows, for a continuous calibration of the modelling toolbox to the changing forest conditions.

We present our modelling framework conceptualization and its early implementation for informing scientists and decision makers.

P1.13

Geocaching as a tool for gamification of recreational forest visits in Latvia

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Abstract

Geocaching is a niche social media and volunteer geographic information activity that has a devoted community starting from the onset of the 2000's. Users place their own caches or find caches placed by others, using coordinates or riddle based puzzles. There are multiple variations of geocaching, importantly, on the scale of difficulty and accessibility of placed caches (for example, caches placed on a vertical altitude or placed in marsh or overgrown vegetation environments). Most often, geocaches are placed to introduce a point of interest, an interesting landscape feature, or a cultural, natural heritage site. Placement and detailing of each cache is up to the user or entity that places the cache, later evaluated and rated by the community.

In this study, we explored some of the existing and novel frameworks of geocache use in forest areas in Latvia, and deducted ways to increase the popularity and accessibility of the activity. We conclude that there is a vast potential both in terms of researching geocaching, and in implementing it in a more official setting through municipalities, forest owners and other stakeholders. The spatial nature of geocaching data provides abilities to model placement, analyze popularity and use GIS tools to assess placement of geocaches. Geocaching may serve as a tool for redirecting visitor flows, rejuvenate less visited areas and provide a gamified experience that can provide useful nature education by incorporating texts and images about the visited area.

P1.14

Theoretical perspective on climate change and disturbances

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Abstract

Understanding how climate change impacts forests is essential to plan management. Assuming no response from trees and forest ecosystems the impacts are potentially devastating. Increasing wind speeds would snap trunks and uproot trees, hotter summer temperatures and stronger droughts weaken and possibly kill trees, more frequent forest fires damage forests in large areas, and biotic disturbances intensify with warmer temperatures. However, trees are responding to risks of disturbances, and this lowers mortality. It is important to consider the time scales in which these responses take place. Chemical defences can strengthen in minutes and trunks fatten in months to resist stronger winds. However, tree species dominance to be substituted in an ecosystem via migration or evolution can take hundreds or even millions of years. In addition, disturbances differ in how trees are hinted of the changes. Trees cannot prepare to resist disturbances that are absent most of the time such as forest fires or many biotic disturbance agents. In contrary, trees can prepare to storms and droughts if wind speeds and soil dryness increase in general. It is important to consider the variable nature of disturbances and the response of trees and ecosystems. For example, it is too simplistic to assume that increasing wind speeds increase storm mortality in the coming decades.

P1.15

Temporal pattern of infestation symptoms by Ips typographus L. in boreal spruce forest in southeastern Finland

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Abstract

The European spruce bark beetle *Ips typographus* L. has significantly increased its outbreak frequency in Finland during the last 12 years. Precise information by terrestrial monitoring of visual symptoms of Norway spruce (*Picea abies* L. Karst.) facilitates both to predict the impacts of I. typographus on stand health, serve as ground truth for remote sensing surveys, and support decision-making to control incipient outbreaks. Our goal was to investigate a temporal pattern of visual symptoms of I. typographus infestation in spruce forests, and to validate the impact of the pest in managed and unmanaged forests.

Stand characteristics and attack symptoms were measured on altogether 63 sampling plots, located in two unmanaged (conserved, 2014–2021) and two managed (2019–2021) forests in southeastern Finland. The area was hit by a summer windstorm in 2010 conducting to eruptive populations of the bark beetle. Severity of *I. typographus* infestation was ranked into three (stem) or four (crown) classes based on occurrence of tree-wise symptoms of entrance holes, resinous flow, bark damage, needle discoloration, and defoliation. Their sum values displayed a total damage score as classified into three severity classes: low, moderate, and a high damage.

The damage score severity was best explained by spruce volume. Damage score value significantly increased in first years and then remained at high level. Beetle-induced tree mortality increased by 4–5 years after an initial attack in conserved forests. Differences in damage score intensity were significant between management regimes, i.e., managed forests suffered from a lower attack intensity and tree mortality, compared to conserved ones. However, also in managed forests the infestation symptoms became more severe over years. Based on our findings, detecting the severity of infestation symptoms can be used in decision-making of forest health management, e.g., in evaluation of need to harvest bark beetle infested trees from forest.

P1.16

Carbon stocks and fluxes in boreal forests along a latitudinal gradient

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Abstract

Carbon (C) sequestrated in the boreal forest ecosystems plays an important role in climate regulation. This study's objectives were to quantify the differences in the components of the forest C cycle along a 1,000 km latitudinal gradient within the boreal region and between dominant coniferous species in Fennoscandia. The study included seven xeric–sub-xeric and eight mesic–herb-rich heath forests dominated by Scots pine and Norway spruce respectively. The total site carbon stock (CS) ranged from 81 to 260 Mg ha^{-1}. The largest ecosystem component CSs were tree stems, mineral soil, and humus layer, representing 30±2%, 28±2%, 33 and 13±1% of total CS respectively. On average, the spruce sites had 40% more C than the pine sites, and CS stored in most compartments was higher on spruce than on pine sites. As exceptions, understorey vegetation and litter layer had a larger CS on pine than on spruce sites. The northern sites had an average of 58% less C than the southern sites. Humus layer CS was the only compartment showing no latitudinal trends. Northern plots had a significantly larger fine and small root CS and understorey CS than southern plots. Most CS compartments were significantly correlated with litterfall C flux components. Dissolved organic carbon (DOC) flux in throughfall was positively correlated with the above ground tree compartment CS. Our study revealed patterns of C distribution in major boreal forest ecosystems along latitudinal and fertility gradients, which may serve as a reference for Earth system models and in the evaluation of their projections.

P1.17

Development of semiochemical-based protection of spruce stands in changing climate.

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Abstract

Climate change intensify synchronous bark beetle outbreaks and weakened tree resistance to bark beetle outbreaks over large areas, challenging forest management capacities to control this important forest pest populations. The use of semiochemicals incorporated in pheromone trap barriers and anti-attractants is complicated by tree resistance to bark beetle attack, the composition of semiochemical mixtures and their release rates, spacing of dispensers, applied management practices and bark beetle population density. Important issues are related to the spillover effect of pheromone traps and switch effects of anti-attractants to adjacent trees. We performed several field experiments using pheromone traps and anti-attractants to protect forest stands. Our first large-scale tree protection experiment was conducted in 2018 during a severe drought period in monocultural Norway spruce stands planted in eastern Czechia, substantially affected by an extensive outbreak of bark beetle *Ips typographus*. Forest management and forest protection measures, especially sanitary felling, were limited here. The use of push and pull strategy did not decrease tree mortality, and a significant switch effect was observed. Beetles colonised the forest edges adjacent to the treatment area. Later, we optimized anti-attractant mixtures with new compounds and the method of anti-attractant applications. The second series of experiments was carried out in spruce stands in central Czechia in 2020–2021. The forest management and tree protection measures were no limited. Finally, we achieved successful results and a strong protective effect of anti-attractants in areas up to 40 m from the treated zone. The use of semiochemicals can be an efficient way to decrease tree mortality rates under the changing climate. The condition for the successful application of semiochemicals is timely sanitary felling implemented across the whole affected area and the use of effective semiochemical mixtures placed with optimal spacing.

P1.18

Future pathways for Arctic forest fires

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Abstract

Wildfires are expected to become more common and more severe in the Arctic states due to climate change. Main cause for the fires is human activity, even in the boreal and Arctic forests. Therefore, activities such forest management and tourism, together with firefighting capacity and readiness, can have a significant impact on future wildfire risks and impacts. To assess the impacts of these factors we have created pathways for future wildfires up to 2050 for the Arctic states. We explore high and low fire activity and risk pathways for all the Arctic states and suggest most our best guess pathways for each state separately. The low activity and fire risk pathway assumes active fire suppression via population participation and official land management, efficient fuel treatments to reduce fire risk, and active firefighting. The high activity and fire risk pathway assumes the opposite due to lack of government and community response, with addition of lacking response to climate-driven changes to wildfire risks. In the Nordic countries, human ignition sources, such as timber extraction, tourism, summer cottages, and expanding wildland-urban intermix due to exurban growth may increase. In addition to these in Canada and Alaska, expansion of agriculture increases the likelihood of open burning of agricultural waste, increasing risk of the fire spreading to wildlands. Drier fuels due to climate change increase the risk of fires, and there is a growing risk of extreme heat conditions, creating favorable conditions for extreme wildfires from any ignition source. Throughout the Arctic lightning is expected to increase, increasing the risk of tundra (specifically grassland) fires, with potential to occur in hard-to-reach locations for firefighting. In short, policy actions and education play a crucial role in future wildfire management and adaptation.

P1.19

Behaviour interventions and in particular nudges as tools to advance climate change mitigation in Finnish forests

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Abstract

To actively mitigate climate change, we need to support the implementation of activities that absorb and store carbon in forests. In Finland, understanding and guiding non-industrial private forest (NIPF) owners' decision-making is the key for the implementation of these activities.

We test an innovative approach for the design of behaviour interventions that could be used to mitigate climate change in Finnish NIPFs. We consider three behaviour interventions that have been little studied in the context of forestry: classical nudges, nudge plus and boosts.

Through 19 forest owner interviews we qualitatively examine the decision-making process related to ash fertilization (AF). We apply a method called the behaviour change wheel (BCW) to recognize factors affecting these decisions and to identify suitable behaviour (and in particular nudge) interventions that could support the implementation of AF.

Most of the factors affecting AF decisions can be categorized under reflective motivation, meaning that these decisions are evaluated and pondered upon carefully. Among the interviewees, the effects of AF are mostly seen positively: it is part of professional, yield-oriented forest management that they are proud to advance. Many trust the expertise of forest professionals and assume that other forest owners' views were similar to theirs. The most mentioned obstacle is the doubt concerning the profitability of AF.

By applying BCW on the data we develop examples of nudge interventions that could be applied to advance the implementation of AF. It seems that these interventions should acknowledge the reflective process involved, indicating that nudge plus or boost may be more appropriate than a classical nudge. Although our findings summarize the views of a specific NIPF owner group on a specific activity, our work provides an approach that can be applied when examining decision-making related to different forestry operations and designing nudge interventions for different NIPF owner groups.

P1.20

Mitigation and adaptation of carbon sequestration in forests by co-creation – HIILIPOLKU

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Abstract

Forest management can affect how much carbon is store in forest biomass and forest soil. Understanding which forest management practices are best-suited for carbon sequestration, water protection and biodiversity, has improved with new research. Reaching the Carbon Neutral Finland 2035 goals, however, requires practice-validated strategies for the implementation of best carbon sequestration methods in forest management.

The main objective of the HIILIPOLKU project (https://www.luke.fi/en/projects/hiilipolku) is to create co-creation practices in partnership with local forestry actors (e.g. landowners, forest service entrepreneurs, NGOs) that nudge carbon sequestration in forests with simultaneous support for water and biodiversity protection. Practices will be based on research information and strive for socially just and rewarding implementation. The model of locally based carbon sequestration produced in the study is conceptualized and its applicability in forest counseling is evaluated nationally.

The HIILIPOLKU study will be carried out in the Puruvesi catchment area. Carbon stocks in trees and soils are calculated and their change is predicted with Motti-simulations and SUSI model using different forest treatment options in the current climate and in future climate conditions. The results of the carbon balance calculations as well as wood production and water impact calculations and the biodiversity impacts from other data sources will be utilized in co-creation process (living lab) in which the best feasible solutions and compensation strategies for socially and economically acceptable carbon sequestration in forests will be developed, while taking water protection and biodiversity into account.

The HIILIPOLKU project is funded by the Ministry of Agriculture and Forestry (+partner organizations). The study is carried out in 2022–2024 under the leadership of the Natural Resources Institute in co-operation with the Finnish Meteorological Institute. The network of local actors has pledged to support the implementation of the project.

P1.21

From trees to soil: how tree diversity and fungi shape soil carbon stocks in mixed species plantations

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Abstract

Mixed-species forestry is a promising approach for sustainable forest management that has the potential to mitigate the impacts of climate change without sacrificing productivity. However, much remains to be understood about the complex and context-dependent species interactions that occur in mixed-species forests, particularly plant-soil interactions to optimize species composition. This study aims to address this knowledge gap by investigating the result of interactions between tree species mixtures, mycorrhizal community structure, and soil carbon stocks in ten tree diversity experiments located in seven countries across Europe and Brazil. The experiments are part of the TreeDivNet, which is a global network of tree diversity experiments. We use detailed soil analyses and amplicon sequencing of soil fungal communities to assess mycorrhizal community structure and functional traits. Preliminary results will be presented exploring the influence of a wide range of tree species identities, mixtures and tree functional groups on soil communities and the dynamics of soil carbon distribution. In addition, we will assess how edaphic and environmental factors, such as pH, soil texture and temperature mediate tree diversity effects on soil. By revealing mechanistic pathways between tree diversity, mycorrhizal communities, and soil carbon distribution, this study will provide critical insights into the potential for mixed-species forestry to promote sustainable forest management and mitigate the effects of climate change. Our findings will be highly relevant for forest managers and policy-makers seeking to develop effective strategies for sustainable forest management.

P1.22

Decision support tool for drained wetlands – ditch cleaning, ecological restoration, left alone

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Abstract

One million kilometres of ditches have been dug across Swedish forest land over the last 100 years to improve forest production. However, many of these are no longer desired because either they are not functional due to poor planning or climate change, or economic or environmental priorities have shifted (which can also be due to climate change). Therefore, this project will create a decision support tool to help decision makers determine which path for managing ditches best fits their goals and situation: ditch cleaning, active ecological restoration, or passive restoration (i.e., left alone). The tool will build off of the Finnish tool SUSI, which models hydrology between ditches, and will incorporate knowledge gained from a ditch management study at Trollberget in the Krycklan Catchment near Vindeln in northern Sweden. One area was restored while four others were clear-cut, of which two were ditch cleaned and two were left alone. Our tool will incorporate data from Trollberget that includes greenhouse gas emissions, biodiversity, ground water levels, nutrient concentrations, site productivity, and runoff water quality metrics. The decision support tool will be upscaled to a national level using Sweden-wide data (e.g., elevation maps, soil maps, and forest inventories). This study is part of a larger Swedish Research Council FORMAS project: Barriers and Opportunities to Managing (BOM) forest ditches for climate.

P1.23

Wetland restoration for the future - ALFAwetlands

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Abstract

The European Union (EU) aims to reduce greenhouse gas (GHG) emissions by at least 55% by 2030. This requires new GHG mitigation measures within all sectors, including Land Use, Land Use Change and Forestry (LULUCF) sector. Sustainable management and restoration of carbon (C) rich ecosystems, such as wetlands, may efficiently contribute to both EU's climate targets and biodiversity by providing cost-efficient climate change mitigation, maintaining biodiversity and water-related services, as well as providing income for landowners. Engagement of local communities in sustainable use and protection of wetlands is highly relevant for enabling transition to a climate-neutral and resilient society across EU. However, significant gaps prevail on wetlands' spatial extent, their magnitude as C sinks and sources, and sustainable restoration measures. This hinders the implementation of efficient C mitigation and adaptation measures in wetlands. ALFAwetlands (www.alfawetlands.eu), a Horizon Europe project (2022–2026), will advance the geospatial knowledge base of wetlands, evaluate pathways of wetland restoration that incorporate a co-creation process, and provide information to maximize climate change, biodiversity and other ecosystem benefits. A wide range of wetlands across Europe will be covered, including floodplains, coastal and artificial wetlands and peatlands. Boreal drained peatland forests and their management options (continuous cover forestry and ecological restoration) will be one of the foci in Estonia, Finland, and Latvia. At the local level, Living Labs support interdisciplinary research on ecological, environmental, economic, and social issues. Models will be used to explore the potential impacts of upscaled wetland restoration options on biodiversity and ecosystem services (BES) provision, as well as changes in BES provision at the EU level for various policy-relevant periods for both climate change mitigation and biodiversity targets. We will assess the socio-economic impacts of wetland restoration, especially on BES benefits and costs of different measures and wellbeing impacts from local to EU levels.

P1.24

Organic soil greenhouse gas emissions in drained and periodically waterlogged old-growth Scots pine forests in hemiboreal Latvia

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Abstract

Tree biomass and soil are significant carbon pools, therefore long-term effect of forest management practices on these pools needs to be evaluated to develop approaches how to increase climate change mitigation capacity of forests and contribute to climate neutrality goals set by the European Union. Recent studies have focused on diverse forest carbon storage and greenhouse gas (GHG) emission aspects on mineral soils, however information about long-term effect of forest drainage on soil GHG flux from old-growth forests on organic soils is scarce. Additionally, large proportion of Scots pine forests on organic soils in hemiboreal region are drained to regulate groundwater level and there is ongoing scientific debate on how to manage these sites in future. The aim of the study is to assess the intra-annual dynamics of carbo dioxide (CO_2) and methane (CH_4) flux in hemiboreal old-growth Scots pine stands growing on organic soils with contrasting groundwater levels. Six Scots pine (*Pinus sylvestris* L.) dominated old-growth forests (130–180 years old) on organic soils with different soil moisture regimes and conditions were selected for seasonal GHG (CO_2, CH_4) flux and environmental parameter measurements. Old-growth forests with contrasting groundwater levels did not result in significant soil CO_2 emission differences. CO_2 flux is mainly affected by soil temperature, interaction between groundwater level (GWL) and groundwater level class (deep GWL > 50cm from the ground surface, shallow GWL < 50cm from the ground surface) and time of season. Old-growth Scots pine forests with deep groundwater level (drained) ensures CH_4 uptake throughout the whole vegetation season. Soil CH_4 uptake or release in sites with shallow groundwater level depends on time of the season and is mainly affected by groundwater level and its fluctuations. Initial drainage of organic soils is essential for long-term climate change mitigation to reduce/accumulate CH_4 fluxes from soil.

P1.25

Methane and nitrous oxide emissions from rewetted forested peatlands

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Abstract

One central goal of peatland rewetting is to prevent carbon dioxide (CO_2) and nitrous oxide (N_2O) emissions caused by drainage-induced peat loss. On the other hand, rewetted peatlands emit methane (CH_4), and so far, scientific knowledge on these emissions is scarce and emission estimates variable. Also, while it can be assumed that N_2O emissions are low after rewetting, the exact size of these emissions is largely unknown.

To fill these knowledge gaps, we measured CH_4 and N_2O emissions at 27 rewetted forested peatland sites in Southern and Central Finland. These sites had been rewetted 1–28 years prior to the measurements; and measurement were conducted during 2021–2022 with portable trace gas analyzers and closed chambers. The sites include eutrophic, mesotrophic and oligotrophic boreal mires that were drained for forestry for several decades and then rewetted by blocking the ditches.

In this presentation, we address the following questions: What is the level of CH_4 emissions after rewetting and how much do these emissions vary? Are N_2O emissions always low at rewetted forested peatlands? Do the N_2O and CH_4 emissions change as the time from rewetting increases? Do the emissions differ between strips and blocked ditches? To what extent tree stand, water table depth and trophic level control the emissions?

P1.26

Detecting Change in Raised Bogs Using Remote Sensing in Häädetkeidas and Kauhaneva, Western Finland

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Abstract

Raised bogs are the most typical wetland type in Southwestern Finland. Because their water and nutrients come from precipitation, they act as markers of changes in climate conditions. The groundwater level in bogs is expected to decrease due to climate change.

The surface of raised bogs is characterized by wet hollows and dry hummocks. Water level fluctuations in hollows can be detected using remote sensing data. A 70-year time series was examined using object-based image analysis and pixel-based classification of aerial images. Water level variation during a single growth season was studied from Planetcope satellite images. The results were compared to weather data from the area.

The results show a decreasing trend in both the amount and the area of wet hollows on raised bogs. In Häädetkeidas, a 13.8% decrease in amount and 14.8 % decrease in area was detected, in Kauhaneva the amount decreased by 5.3% and area by 6.8%. The change is interpreted as the result of a drop in the groundwater level. The mean temperatures in the area have risen over 1 °C during the same period.

Uncertainty to the results is caused by changes in water level during growth seasons, detectable from high-resolution satellite images. The variation is mainly caused by differences in the amount of meltwater in spring. This can affect the results obtained from aerial images.

Climate warming has resulted in less snowy winters in Northern Hemisphere. This can lead to lowering of groundwater levels in bogs and changes in raised bog ecosystems, including increased forestation, and decreasing of open landscapes.

Keywords: Remote sensing, climate change, raised bogs, geomorphology, GEOBIA

Reference:

Talvitie, P., 2022. Keidassoiden pintarakenteen muutosten havainnointi kaukokartoitusaineistojen avulla. (Detecting change in raised bogs using remote sensing). Master's thesis, Master's programme in Geoinformatics, Aalto University, Helsinki, Finland. 109 p.

P1.27

Optimization of parameters of HIMMELI methane model to drained peatland forests with flux and concentration measurements

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Abstract

In Finland, 5.9 million hectares of peatlands have been drained for forestry. Drainage enables better growth of trees, but it also exposes the organic matter of the soil peat, accumulated in anoxic conditions during thousands of years, to oxygen and consequently, carbon can be lost into the atmosphere as carbon dioxide (CO_2). On the other hand, drained peatlands are not usually sources of methane (CH_4), unlike pristine peatlands, but rather a sink for this strong greenhouse gas. In order to predict future carbon balance and the impacts of management practices on peatland GHG exchange, models are needed. Several models designed for simulating peatland methane emissions exist, but models targeted specifically or applicable to drained and managed peatland forests are rare. We are developing our peatland methane model HIMMELI to be able to simulate also managed peatlands in a reliable way.

Many CH_4 models have been calibrated by optimizing their parameters using flux measurement data. Our aim was to calibrate HIMMELI to drained peatland forests, utilizing not only flux data (CO_2, CH_4) but also simultaneous measurements of gas concentrations (CO_2, CH_4, oxygen) in the soil. The study was conducted at two drained peatland forest harvest experiments in southern Finland. Total of 17 parameters were optimized separately for different harvest treatments using a local optimization algorithm with appropriate weights and cost functions for the flux and concentration data. The addition of concentration data was beneficial judging from the optimal parameter values and model output being significantly different depending on weight of the concentrations relative to flux data.

Results of this study provide new information about the model performance and they will be utilized in further simulations of GHG exchange on managed peatlands.

P1.28

Impact of rewetting on the carbon balance of a drained nutrient-poor peatland forest in Northern Sweden

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Abstract

Natural peatlands represent a small but important long-term carbon sink. For forest management approximately 1.5 to 2.0 million hectares in Sweden were drained over the past century. The Nordic countries have therefore identified peatland restoration as part of its strategy to reduce greenhouse gas (GHG) emissions in the land use sector. However, while peatland restoration may lead to reductions in CO_2 emissions from drained peatlands, rewetted peatlands show initially higher CH_4 emissions. Most empirical evidence in the boreal zone was obtained from sites in Finland, while data is lacking in Sweden. In our study, we investigate the spatial variability of GHG exchange before and after peatland rewetting, determine the biogeochemical factors that govern these variations and examine the overall impact of rewetting on the GHG balance of a drained peatland forest in boreal Sweden. We use the manual closed-chamber method to measure the soil-atmosphere fluxes of CO_2 and CH_4 along six transects at the Trollberget rewetted peatland forest near Vindeln, Sweden. The rewetting actions at the site were carried out in November 2020 and a drained section has been kept as control near the outlet of the mire. We observe higher CH_4 emissions and lower CO_2 emissions compared to drained conditions, however, no significant change in the net soil-atmosphere C exchange within the initial years following rewetting.

P1.29

Quantification of the reasons for the lake Kukkia brownification

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Abstract

Browning of surface waters due to increased terrestrial loading of dissolved organic carbon is observed across the Northern Hemisphere. Brownification is often explained by changes in large scale anthropogenic pressures (acidification, climate and land use). We quantified the effect of environmental changes on observed brownification of an important bird lake Kukkia in Central Finland. Water bird densities have decreased during last decades, partly due to brownification of the lake. We studied past trends of organic carbon loading from catchments based on observations since 1990's. We created scenarios for atmospheric deposition, climate and land use change to simulate their quantitative effect on brownification of the lake by process-based models (PERSiST for hydrology, INCA-C for carbon loading and MyLake for carbon processes in the lake). Changes in forest cuts has been the primary reason for brownification of the lake. Decrease in acidic deposition has resulted in a lower leaching of dissolved organic carbon, but the effect is small. Runoff and TOC leaching from terrestrial areas to the lake is smaller than it would have been without observed increasing trend in temperature by 2 degrees.

P1.30

Dead better than alive – the case of retention trees and microhabitats in hemiboreal forests

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Abstract

Retention trees are selected as one of the measures for the maintenance of biodiversity in managed forests. They improve the structural richness of young stands and provide tree-related microhabitats (TreM). Yet, ecological trees are subjected to drastic changes in the environment (drought, wind) after the harvest, affecting not only their growth but often also their survival and leading to questions on their actual role as a measure of biodiversity maintenance.

In this study, we assessed the linkage between TreMs and retention tree dimensions, species, and status (living or dead). The data collection took place in 20 young stands in Latvia where conventional harvesting was done from 2002–2004. In each stand at least 15 living and all dead retention trees were measured and TreMs were assessed based on the methodology of Larrieu et.al., 2018. In total 274 retention trees were evaluated, from which 168 had TreMs. Since the conventional harvest 39 of the retention trees had died off forming different types of dead wood in the stand.

Tree diameter and species had a statistically significant effect on the number of TreMs. Positive dependence on tree diameter was identified. Species such as goat willow (*Salix caprea*), Eurasian aspen (*Populus tremula*), and common ash (Fraxinus excelsior) had the highest numbers of TreMs detected. The ecological role of retention trees was somewhat positively affected by their death since the dead wood had a significantly higher number of TreMs compared to living trees.

P1.31

Effects of alternative logging practices on spider communities in spruce mires

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Abstract

Spiders play an essential role in maintaining the health and biodiversity of forest ecosystems. They have important functions in forest ecosystems as predators of insects and other arthropods, which includes a contribution to controlling pest populations. Spiders are also an important food source for many animals, such as birds. Continuous cover forestry (CCF) with selection harvesting is suggested to have less negative effect on peatland ecosystem than clear-cutting, but the effects of forest management practices on species diversity remain an understudied topic. We collected spider assemblages from three forest plots representing clear-cut, CCF and non-harvested control in the experimental study site on spruce mires in Ränskälänkorpi, southern Finland. Intensive sampling of the plots was conducted one growing season after harvesting, using standardized methods, that enables species to be connected to specific microhabitats. The sampling techniques included pitfall trapping (ground level), sweeping (understory), beating (trees) and aerial sampling (web builders). All adult spiders were identified to the species level, and the total observed species richness was 121. Our results show major differences in the spider community composition between different treatments (clear-cutting, selection harvesting of CCF and non-harvested control), which promotes the potential of spiders as bioindicators. Moreover, we show how the predatory functions of the spider community change after harvesting. The CCF site had the highest species richness, supported by the intermediate disturbance hypothesis. The clear-cut site had expectedly the lowest functional diversity but also the lowest species richness. This result refutes some of the previous findings.

P1.32

Boreal forest biodiversity assessment using unmanned aerial systems

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Abstract

Species richness is one of the most common measures to assess biodiversity. European aspen (*Populus tremula* L.) is a keystone species for biodiversity of boreal forests. Large-diameter aspens maintain the diversity of hundreds of species, many of which are threatened in Fennoscandia. Due to a low economic value and relatively sparse and scattered occurrence of aspen in boreal forests, there is a lack of information of the spatial and temporal distribution of aspen, which hampers efficient planning and implementation of sustainable forest management practices and conservation efforts. Standing dead trees are well known to be an important habitat structure for several species in different groups of organisms. Thus, mapping standing dead trees, especially, in natural forests is very important for evaluation of the forest's health status, and its capability for storing Carbon, and the conservation of biodiversity.

Nowadays airborne remote sensing techniques are commonly used for biodiversity assessment over the large areas, however, operational costs of data acquisition are still relatively high and there is strong dependence on the availability and quality of field data. New unmanned aerial systems (UAS) based remote sensing proved to be very efficient in providing ultra-high spatial and temporal resolution data for detailed forest properties assessment at reasonable costs and serve as a supplement or even able to replace part of the currently required field work to support biodiversity assessments.

In this study, the main objective was to assess identification of European aspen and standing dead trees at the individual tree level in a southern boreal forest using high-resolution photogrammetric point clouds derived from RGB and multispectral images and light detection and ranging (LiDAR) data acquired with an unmanned aerial system.

P1.33

Mix of broadleaved trees in coniferous forests boosts vascular plant diversity

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Abstract

Understorey vegetation constitutes a remarkable part of the total biodiversity of boreal forests. Understorey plants therefore provide a range of ecosystem services, the maintenance of which belongs to the main targets of sustainable forest management. Here, we investigated how the proportion of broadleaved trees (BLT%), tree species richness (TreeS), stand density, and shrub cover% were reflected in the number of vascular plant species (VascS) and cover% of herbs and bilberry (*Vaccinium myrtillus*) in the southern and middle boreal subzones in Finland.

VascS increased along with increasing BLT% and TreeS on mesic and xeric plots in both subzones. On the other hand, high stand density was negatively related to VascS, especially on mesic sites. The cover of herbs generally increased with BLT%, while that of bilberry showed either positive or negative responses. Similarly, shrub layer cover often resulted in unimodal responses in the understorey vegetation.

We conclude that a slight increase of BLT% in mixed coniferous production forests maintains biodiversity and ecosystem services of understorey vegetation, given that high stand density may counteract these positive effects.

P2.1

Influence of soil disturbance by site preparation or stump harvesting on seedling regeneration of Norway spruce and Scots pine

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Abstract

Site preparation by disc harrowing or patch scarification are standard methods to facilitate seedling establishment and growth following clear-cutting. The soil disturbance from stump harvesting can reduce the need for additional site preparation. We compared the effect of these management practices on Norway spruce and Scots pine seedling regeneration.

Three field experiments in different climate regions of Sweden were studied, each with a randomized block design (n=4). Following clear-felling and harvest of logging residues, the treatments were: no site preparation (control), patch scarification (PS), disc harrowing (DH), and stump-harvesting (SH). Seedling survival and height increment were repeatedly measured up to 5 years following clear-cutting and plantation. Causes to seedling damage and mortality were assessed from visual inspections.

Soil disturbance (% of soil surface) increased in the order Control < PS < DH < SH. Scots pine regeneration at a sandy soil in Central Sweden was equally successful in all treatments except in the undisturbed control (0), where both height increment and survival rate were significantly much lower. Norway spruce regeneration in a sandy loam soil in South Sweden showed higher height increment after stump harvest and site preparation treatments compared to control. Attacks by the large pine weevil Hylobius abietus were abundant and decreased seedling survival particularly in Control treatment. On the contrary, Norway spruce seedling height and survival was highest in Control and lowest at stump harvested treatments a site in N Sweden with sandy loamy till. In conclusion, stump harvesting had effects more similar with standard site preparation methods than with seedling established at undisturbed sites.

P2.2

Infestation patterns of multi-species coniferous forests by two bark beetle species in Kunashir Island in the Far East

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Abstract

Global climate change triggers to shift of bark beetle outbreaks to previously non-susceptible locations in the Far East region. Massive bark beetle outbreaks were not studied in Kunashir Island (Far East, Russian Federation) before. Only entomological studies on the determination of bark beetle species were carried out earlier. This provides an excellent opportunity to understand the dynamics and phases of bark beetle outbreaks in regions with marine climates.

This research covers windfall and barks beetle outbreaks in the period 2015–2021 in the southern part of Kurilskiy Nature Reserve. The massive bark beetle outbreak after a windfall caused significant tree mortality. The total disturbance area equals 620.5 ha (about 4% of the study area; 72% - of windfall area, 28% - of dead wood area) for the south of this part reserve.

Sentinel 2 images were used to identify standing tree mortality using unsupervised classification and windfall areas were selected from forest loss Hansen's dataset. Further, these data together with the forest inventory data were used to analyze the main drivers of disturbances caused by wind and bark beetle outbreaks.

We use the boosted regression trees to analyze the main drivers for initialization and severity of wind disturbances and bark beatle outbreaks by phases. As predictors, we used set of forest (tree species percentage, height, age, growth rate) and environmental characteristics (slope, elevation, solar radiation). The bark beetle outbreak was split into phases. First is the transition of bark beetles from colonized downed trees to standing trees and second is during spreading of beetles in standing trees.

Results of our research showed that stand tree characteristics are more important for the possibility of a bark beetle outbreak than the environmental characteristics in both phases for the southern part of the reserve.

P2.3

Phenological Modelling of spruce bark beetle and drought risk in framework of TANABBO II model

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Abstract

Global warming plays the main role in disturbances in forest ecosystems by the bark beetle outbreaks. Decreasing precipitation and increase in the frequency of drought periods create conditions for the water stress of trees. The European Spruce Bark Beetle (*Ips typographus* L.) is a more dangerous pest for Norway spruce (*Picea abies* (L.) Karst.) forests in Central Europe under these conditions because even healthy trees under water stress have fewer chances of surviving in massive spruce bark beetle outbreaks. TANABBO II system was developed for spruce bark beetle prognosis at forest stand level and had operational, prognosis parts. The operational part includes modules of phenological modelling PHENIPS, a drought assessment model for analyzing water stress conditions. Prognosis part assessment of spruce bark beetle distribution based on forest inventory data and satellite imageries. The study area is Horní Planá region in Central Europe managed by the Military Forests and Farms of the Czech Republic. Drought assessment for this area was done based on the everyday calculation of Drought Indexes (DI) and Deficit Transpiration Indexes (DTI) and the number of generations of spruce bark beetle were calculated based on the PHENIPS model. Phenological modelling and drought assessment were made using forestry data, Digital Elevation Model (DEM) and meteorological data (mean, max daily temperatures, daily solar radiation. Validation of the obtained prognostic data was carried out by comparing these data with the number of bark beetles caught in traps on certain days. Based on the results of the simulation experiments it is concluded that the presented system is a promising tool to analyse the dynamic interaction of disturbances by Ips. typographus, environmental conditions and forest structure as affected by natural forest development and management interventions. Limitations of the TANABBO II model and possible approaches for extensive validation against empirical damage data are discussed.

P2.4

How invasive tree species impact the growth of native trees in temperate forests?

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Abstract

Invasive tree species are considered one of the biggest threats to forest ecosystems. The negative impact is related not only to ecological, but also economic aspects. Invasive trees can transform the environment including microclimate, soil, and light conditions. All these factors can impact tree growth. We investigated the impact of invasive tree species on the growth of major native tree species. Both *Prunus serotina* and *Robinia pseudoacacia* have different nitrogen uptaking strategies and foliar chemical composition, thus we expected their impact on local ecosystems will differ. We established 72 0.05 ha plots (24 plots each for *P. serotina* invaded, *R. pseudoaccacia* invaded, and non-invaded stands) in western Poland managed forests. Stands were in the middle and mature age, growing in two different habitats: nutrient-poor dominated by *Pinus sylvestris* and fertile dominated by *Quercus robur* and *Q. petraea*. We choose plots with various abundance of invaders to study how changes occur along the quantitative gradient of invader biomass. We collected tree core samples from five trees on each plot. The measurements of growth over the last ten years were made with CDendro and CooRecorder software. Invasive tree species consume environmental resources, but also fertilize the soil by litter fall. Our study revealed the per capita effects of studied invasive tree species on native stand growth, revealing the consequences of the invasive tree species presence in forest ecosystems. Our results will support the management of invasive tree species populations in managed and protected forests. It can be used in large-scale management plans to determine overall effects on landscape and regional scales. The study was financed by the National Science Centre, Poland under project no. 2019/35/B/NZ8/01381 entitled "Impact of invasive tree species on ecosystem services: plants biodiversity, carbon and nitrogen cycling and climate regulation".

P2.5

How do alien tree species affect natural regeneration in temperate forests?

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Abstract

The invasion of alien species is one of the biggest threats to biodiversity and sustainable forest management. Due to their abundance and life history traits, invasive trees affect the biodiversity and functioning of all forest strata, including natural regeneration. We aimed to assess the impact of two invasive tree species: *Prunus serotina* and *Robinia pseudoacacia* on native species natural regeneration diversity and density along the gradient of invader biomass. We hypothesized that higher biomass of invasive species will decrease the diversity and density of native forest-forming species, and the effects of both studied invaders will differ, due to differences in life history traits. We used a set of 72 plots in managed forests of western Poland, established along invasion gradients in nutrient-poor *Pinus sylvestris*-dominated stands and fertile stands dominated by *Quercus robur* and *Q. petraea*. Within each 0.05 ha plot we measured trees DBH to assess biomass and we counted the natural regeneration of each species within four 28.27 m^2 subplots. Using generalized linear mixed-effects models we assessed marginal responses of species richness and density of main forest-forming native species as a function of stand type, soil fertility, and invader biomass. We revealed the quantitative effects of invasive tree species on native species regeneration per invader biomass unit. These results allow for risk assessments and quantifications of ecosystem resilience ability, necessary for evidence-based management of alien tree species in forestry. The study was financed by the National Science Centre, Poland under project no. 2019/35/B/NZ8/01381 entitled "Impact of invasive tree species on ecosystem services: plants biodiversity, carbon and nitrogen cycling and climate regulation".

P2.6

Recovery after large scale disturbances: the power of vegetation patches

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Abstract

Large scale disturbances, such as volcanic eruptions and open mining operations, often completely erase the vegetation cover and destroy soil communities, prompting primary succession. Primary succession is a slow process, and many years are needed until the vegetation grows strong enough to prevent landslides or flash floods from runoff precipitation. To reduce the risks of such events, active interventions, such as revegetation by planting trees in critical areas, can accelerate the development of vegetation cover. However, these artificial plantations might foster different plant communities and species diversities compared to naturally recovered forests, resulting in long-term negative impacts in exchange for short-term positive ones. Is there a better approach which maximizes recovery speed but retains advantages of natural succession? By investigating vegetation patch dynamics and comparing plant species diversities and communities among several forest types after volcanic eruptions, I propose that planting trees and shrubs in patches near each other fosters quick recovery and native species composition. Observations at the volcano Mount Usu (Hokkaido, Japan), showed that in the early stages of recovery, natural vegetation patches expanded faster and had denser vegetation if they were clustered close to each other. Similarly, plantations with patch-like design encouraged the establishment of native species, by protecting fresh recruits from the harsh environment in the open spaces between the planted trees, resulting in higher species diversity and native species composition. Although the planted tree species changed canopy composition compared to natural forests, the understorey layer trended toward natural species compositions if appropriate species were selected during the planting phase. In summary, if quick recovery is desired after large scale disturbances, spatially heterogeneous, patchy planting design are better than dense, homogeneous plantations in reaching natural species compositions and diversities.

P2.7

Use of digital tools for facilitating forest recreational visits in Latvia.

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Abstract

In Latvia, forest recreation is a broad and complex tradition, yet often overlooked in terms of research and analyzing the underlying social processes and nature impacts. The use of digital tools and applications in the context of visiting forest areas for recreational purposes holds great potential in terms of both utilizing data for forest area management and developing interactive platforms for nature education and facilitating positive outdoor behaviors. Information on special regime areas, restricted sites, scenic objects or points of interest can be digitized and accessed for augmenting casual or more advanced forest visits. Here we present some results of a three-part research on the topic. Our national scale survey indicates that only 25% of respondents utilized a GPS type application or map in their forest area recreational visits, and 6% of respondents used a nature education application to augment their visits. Our express surveys show that services like Google Maps were most popular for planning recreational visits. During our interviews with outdoor activity organizers, the importance of open source and fine scale data on roads and pathways was identified, for practical purposes of planning and conducting events. These results showcase a clear importance for digital tools in the process of planning recreational activities and during them, yet we find that the general interest on more advanced tools and data sources remains rather low.

P2.8

Effect of drought and pine weevil damage on mechanically protected Norway spruce seedlings

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Abstract

Pest damage to conifer seedlings, such as that of pine weevil (*Hylobius abietis*), has historically been supressed using chemical insecticides. Over the past few decades however, insecticides have largely been banned for use in forestry, due to their problems with toxicity. Nevertheless, the problem of pine weevil damage remains and novel methods of protection are urgently needed. To address this, we tested performance of five different mechanical protection methods as well as commercial insecticide and ambient control on Norway spruce (*Picea abies*) seedlings. 7 study sites were established in south Sweden in 2018 with 7 more in 2019 and seedlings were then surveyed for survival and growth for four years. We found no significant difference in protection methods on growth and no significant difference between protection methods on survival, i.e., mechanical protection methods performed equally well as insecticide. Average survival after four years for the protected seedlings in the 2018 dataset was around 70% for both mechanical and insecticide protections while survival of untreated seedlings was around 60%. Moreover, summer of 2018 was exceptionally warm and dry, providing an opportunity to study the effects on drought on seedlings when combined with different levels of pine weevil damage. When comparing the two datasets, initial results indicate that there may be additionality between drought and pine weevil damage, which is only present in the 2018 dataset. This could potentially be explained by additional stress that drought puts on seedlings, thus even the ones with low levels of pine weevil damage may be pushed into mortality sooner.

P2.10

Soil microbial and extracellular enzymatic responses to experimental extreme warming and drought conditions

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Abstract

Climate changes including increased frequency of extreme climate events, such as extremely high temperatures and regional droughts, potentially have both direct and indirect impacts on soil microbial organisms. However, the process and scale of the responses remain unclear. This study investigated the effects of extreme warming and drought conditions on the soil microbial biomass and extracellular enzyme activities in the soil covered with 2-year-old *Pinus densiflora* seedlings. Based on SSP5-8.5, open field treatments of 87-day extreme warming (+4°C) using infrared heater and 33-day drought (100% rainfall interception) using vinyl barrier were applied from May to August, 2022. Soil microbial biomass carbon and nitrogen and extracellular enzyme (acid phosphatase, β-glucosidase, N-acetyl-glucosaminidase, and leucine aminopeptidase) activities were measured once a month from the cessation of the drought treatment to the end of the warming treatment (three times in total). Compared to those under the precipitation control, microbial biomass carbon under the drought treatment significantly decreased by 39.64% at the first measurement, and the microbial biomass nitrogen decreased by 62.70%, 46.77%, and 63.77% at the entire three measurements, respectively. The activities of acid phosphatase at the third measurement increased significantly by 34.73% under the warming treatment than those under the warming control, while other enzyme activities showed no responses during the experimental period. The overall results indicate the sensitivity by each element of soil microbial and extracellular enzymatic responses to environmental variables. Since this study identified the effects of only a specific extreme climate phenomenon for a limited period, future studies based on a wider range of environmental and temporal gradients over a long period are needed to track the soil microbial responses to climate change.

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P2.10

How plants response to changing seasonal snow conditions? - A meta-analysis

Yihan Cai, Makoto Kobayashi

Hokkaido University, Japan

Abstract

In temperate, alpine and polar environments, plants may be covered with seasonal snow more than half a year. In these habitats, snow play an important role for plants survival and growth by providing them a shelter from freezing air and keeping the temperature around 0 degrees Celsius under the snow. According to the global warming, however, the change in snow accumulation amount and duration became more and more significant, which could lead some crucial impacts on plants survival and growth. Previous studies indicated that earlier snowmelt would increase the physical damages and mortality rate on plants via late frost and affect their growth in the following growing period. On the other hand, some studies found that plants biomass and height increased more in the snow decreasing condition. One interesting issue raising then is why the plant response to the changing snow conditions are different among studies, in other words, what factors created these differences. To solve this question, we conducted a meta-analysis by gathering all papers studied about plant responses to changing snow conditions. In the analysis, we divided seasonal snow changing into four conditions, 1) snow decreasing, 2) snow decreasing and warming 3) anow adding, and 4) snow adding and warming. Plants survival rate, height, biomass and length of above- and below-ground, cover rate were extracted as response variables. Plant functional types and growth stages, latitude, altitude, climatic zones, ecosystem types, soil types, mean annual temperature, annual precipitation, snow maximum depth and some other environmental factors were extracted as explanatory variables. Subgroup analysis and meta regression analysis were conducted when each effect size was influenced more by heterogeneity than by sampling error. This study would enhance our understanding of plant responses to seasonal snow change under climate warming.

P2.11

Soil and deadwood CH_4 fluxes in response to forest management and climate change

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Abstract

Upland forest soils are commonly sinks of CH_4 – the second largest contributor to climate change – but the effects of forest management and climate change on forest CH_4 cycling are not well understood. Further less is known about the role of deadwood in the forest CH_4 cycle but recent studies indicate that deadwood is a net source of CH_4.

In the ForBioFunCtioN-project, we utilize state-of-the-art technology (LI-7810 Trace Gas Analyzer, LI-COR®) for *in situ* measurements of soil-atmosphere and deadwood-atmosphere exchange of CO_2 and CH_4 in an extensive climate and management manipulation experiment. Treatments include warming with open-top chambers, increased precipitation (55 mm/year during snow-free period), N fertilization (NH_4NO_3 150 kg/ha) and biochar addition (10 t/ha) in a total of 12 treatment combinations (n = 144) across five Norwegian spruce dominated bilberry forest sites spanning from a recent clear-cut to mature managed (80 years) and old unmanaged (140 years) stands.

Here, we present the experimental setup of ForBioFunCtioN and soil and deadwood CH_4 flux measurements from the snow-free period in 2021 and 2022. Initial results showed that N fertilization decreased net soil CH_4 consumption and that, while at rare occasions functioning as a sink, the Norwegian spruce deadwood was almost exclusively a source of CH_4. The source strength of deadwood differed substantially between sites but CH_4 efflux from deadwood increased by biochar addition at all sites.

P2.12

Application of Russian State Forest Inventory data in the inventory of greenhouse gases

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Abstract

National Forest Inventory (NFI), a sample-based forest survey, is recognized internationally as a reliable source of information, which can be integrated in the reporting under the UNFCCC and the Paris Agreement. Statistically proved sample of repeated measurements allows reliable estimates of change in forest carbon pools.

The first cycle of Russian State Forest Inventory was finalized in 2020. In total, 69.1 thousand permanent 0.05 ha sample plots were established during 2007-2020 (https://roslesinforg.ru/services/gil/). The second cycle of Russian NFI is started in 2021 and aims to be accomplished by 2030. The NFI is a new information source for Russian forest, that require analysis to develop a procedure for its utilization in particular for the national greenhouse gas inventory in the Land Use, Land Use Change and Forestry (LULUCF) sector.

The Russian NFI provides characteristics of forests aggregated at regional and national scale, including distribution of forested area and growing stock volume (GSV) by dominant tree species, 10-year age classes, and level of productivity (site index), as well as a number of other indicators. A single NFI census makes it possible to estimate carbon stock, but not direct estimation of C change (increment) unless model-based.

We aimed at live biomass increments and changes in deadwood based on the results of the first cycle NFI by applying several regionalized empirical models, including (1) growth models (Shvidenko et al. 2008) – to estimate GSV increment based on species, age and site index; (2) Biomass expansion factors (Schepaschenko et al. 2018) – to convert volume increment to live biomass C sequestration; and (3) deadwood conversion factors (Shvidenko et al. 2022) – to estimate deadwood C pool and its change based on GSV. With this method, we obtain the gross gain in Russian forest live biomass and deadwood at regional level and annual step.

P2.13

Changes in leaf litter flammability depending on how the litter layers overlap

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Abstract

Climate change has been changing the fire regime in forest ecosystems. Leaf litter is the main fuel for surface fires which is the dominant type of forest fire worldwide. Leaf flammability is known to be determined by both morphological and chemical characteristics. Meanwhile, in a mixed forest, leaf mixes each other in various ways depending on the interspecific timig of litter fall, for example. However, it is not known how the different types of litter mixture changes the litter flammability. We conducted a burning experiment using the litter of both broad-leaved species and coniferous species dominant in sub-boreal forests of northern Japan. Experimental results show that when the coniferous litter overlapped broad-leaved litter, the burning time was longer than when only broad-leaved litter was burned . It was found that the maximum temperature was higher when the broad-leaved litter were mixed or overlapped with coniferous litter as compared with the case when only the coniferous litters were burned. These results indicates that the litter flammability of coniferous forests might increase if broad-leaved trees increase due to climate change in the future of northern Japan.

P2.14

Soil fungal community and soil carbon storage in boreal Norway spruce forests as affected by continuous-cover forestry and rotation forest management.

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Abstract

Boreal forests store more than 30% of the global terrestrial carbon (C), which is mainly stored in the forest soil. C sequestration is driven by roots and associated fungi. Forest management affects the C dynamics and the soil microbial community of forest ecosystems. Root associated fungi are abundant in boreal forests and especially ectomycorrhiza (ECM) play an important role in the accumulation and stabilization of soil C. In this study, we compare continuous cover forestry (CCF) and rotation forest management (RFM) - and their effects on the fungal community composition in boreal spruce forests to draw conclusions regarding the potential long-term soil C storage under these management systems.

We carried out measurements on Norway spruce (Picea Abies Karst.) dominated experimental forest plots of the Natural Resources Institute Finland in Vessari, central Finland. The stands are managed with logging methods characteristic for CCF and RFM since 1985/86. We included the treatments: (1) CCF, (2) RFM, (3) RFM and (4) uncut reference forests.

Under CCF we assumed a higher fungal abundance, a different fungal community composition and different functionality of mycorrhiza caused by continuous belowground C inputs through roots and litter and by less disturbance of the fungal community. We hypothesized that reference forests and CCF harbor a more diverse ectomycorrhizal community than clear-cuts and RFM stands. Whereas on clear-cuts, we expected more saprotrophs and plant pathogens due to high amounts of harvesting residues. Furthermore, we expected that the shift of tree dominated vegetation to herb and grass dominated after clear-cutting shifts the dominance from ECM to arbuscular mycorrhiza, which are considered less efficient in building up recalcitrant C pools.

We will present results of the fungal community composition, fungal necromass and the abundance of condensed tannins and discuss their implications regarding potential effects of the forest management on soil C storage.

P2.15

Uneven-aged forestry and recreational values; Understanding the nexus between Swedish urban forests and continuous cover forestry.

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Abstract

Our research seeks to provide updated information on uneven-aged forest management methods available in Sweden. The goal is to identify the challenges of uneven-aged forestry in urban forests, with a special focus on understanding the behavior of both forest owners and visitors. The project consists of different stages with the first one set to identify currently used methods in Swedish urban forests. The later stages of the project seek to contact both forest owners and visitors to find valuable insights on how to assess the transition to an uneven-aged forestry model. As of now, the research is in its first stage; results intend to show the unique forest ownership dynamics observed across the country and their relation to both urban forestry and continuous cover forestry. In this initial stage, the literature brings forward challenges in creating a common understanding of urban forests in a country-specific context. We also highlight the need for a new definition of the term “Urban”, which should apply to the country's deep relationship between forests and cities.

P2.16

Carbon storage, biodiversity and ecosystem services of northern boreal peatland forests

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Abstract

Finland aims to be carbon (C) neutral by the year 2035 and EU by the year 2050. To achieve these targets, new measures from peatland forests are needed to reduce net greenhouse gas (GHG) emissions. We assessed the C reduction at Ii municipality (Northern Ostrobothnia) peatland forests through C storage in living trees and soils. Future C storage in forests depends largely on how they will be managed. We considered several management alternatives representing traditional rotation forestry and continuous cover forestry on peatland forests and included an energy wood harvesting alternative. Along with the C reduction, we assessed impacts of forest management alternatives on biodiversity and ecosystem services (BES) based on available data (i.e., Metsäkeskus) and models (i.e., tree growth model and biodiversity model). To assess the impact of forest management alternatives, we simulated forest growth by utilizing the SIMO simulation, which calculates the net present value of timber production, variables describing stand characteristics and harvests, C storage and BES indicators. Finally, we will also discuss how alternative management in peatland forests could help in the planning and decision making in the mitigation of climate change.

P2.17

Context dependent usefulness of nitrogen fixing trees for the restoration after landslides in sub-boreal forests

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Abstract

Under the climate change, the increase of heavy precipitation is predicted and this increase of heavy rain is concerned to trigger frequent landslides. Therefore, the efficient strategy to accelerate re-vegetation of damaged ecosystem by landslide is urgently required. Plantation of the nitrogen (N)-fixing trees is one of the promising way to accelerate the forest recovery after severe disturbance. Although the legume is most-dominant group of the N-fixing plants, there are many non-legume N fixing plants across the world. However, the difference of plantation efficiency between legume and non-legume trees are little understood. Furthermore, to know the general conclusion about the intergroup efficiency of the two nitrogen fixing trees, it is necessary how the plantation efficiency differ across the variable environmental context. In this study we compared the plantation efficiency (survival rate) of Lespedeza bicolor (Fabaceae) and Alnus hirsuta (Betulaceae) after 15 artificially established landslides in variable environmental context in northern Hokkaido. In general, the survival rate of Alnus hirsute was higher than Lespedeza bicolor. While the soil type (either brown forest soil or serpentine soil) was the main driver of the differential survival rate of Alnus hirsute, slope angle, soil water contents, and soil texture were the determinant factors for the survival rate of Lespedeza bicolor. Interestingly, the survival rate of Lespedeza bicolor was higher at steeper slope as compared to the gentler slope, probably because of the less herbivory by deers at steeper slope. Our results indicates that for the efficient reforestation of post-landslide forests, it is necessary to understand the context dependent efficiency of plantation for a variety of nitrogen fixing trees.

P2.19

Habitat segregation and trait variations of two Labrador tea species across permafrost gradients in interior Alaska

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Abstract

Permafrost is one of the most significant environmental factors determining boreal ecosystems, and the influences of permafrost thawing due to recent rapid global warming on circumpolar vegetation have been a concern. However, it has not been examined how understory shrubs that dominate such boreal ecosystems adapt to permafrost conditions. We focused on two Labrador-tea species (Ericaceae: *Rhododendron* subsect. *Ledum*) inhabiting a wide range of boreal ecosystems: *R. groenlandicum* and *R. tomentosum*. Their populations, leaf traits, and environmental habitats were examined across two permafrost gradients in discontinuous permafrost regions in interior Alaska. In both species, the numbers of ramets were significantly associated with soil water content and canopy openness rather than active layer thickness, but the trends were contrastive. *Rhododendron tomentosum* was more common under lighter wetter permafrost conditions, whereas *R. groenlandicum* was more dominant under darker drier less-permafrost conditions. Compared to *R. groenlandicum*, *R. tomentosum* had smaller leaves, higher leaf mass per area (LMA), higher leaf dry mass content (LDMC), and higher sapwood area per total shoot leaf area (Huber value). This suggested that the leaves of *R. tomentosum* were more conservative than those of *R. groenlandicum*. As for the intraspecies variations, both species had more conservative leaves in the sites under greater permafrost influences. Therefore, habitat segregation due to permafrost may occur between the two Labrador-tea species in the discontinuous regions in interior Alaska, and more conservative leaves can be adaptive under permafrost conditions.

P2.19

Biotic responses to management in black alder woodland key habitats

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Abstract

Woodland key habitat forest sites are assumed to host rare and endangered species with highly specific demands for the habitat, unattainable by conventional forest management. Therefore, creation of buffer zones around them is practiced. However, the effect of such an approach has not been thoroughly evaluated. In this study the short-term effectiveness of buffer zone establishment in black alder Woodland Key Habitats was investigated in terms of maintenance of conditions suitable for habitat specialist species.

To achieve this, 6–9 sample plots were established in 10 black alder Woodland Key Habitats, using the BACI (Before – After – Control – Impact) experiment design approach. Each study site was divided into two sections – potentially influenced (plots located up to 60 m from the edge of the cutover) and control part (plots located further tan 60 m from the edge). Stand structure (tree species, dimensions), Coarse Woody Debris, indicator species and habitat specialist species: lichens, polyporous fungi, vascular plants and bryophytes, molluscs were evaluated. Species diversity was represented by different diversity indices, environmental factors – by Ellenberg indices.

Overall 11 signal species (IS and HS) of bryophytes, 7 vascular plants, 7 lichen, 7 mollusc and 15 polypore species have been observed. No noticeable changes in environmental conditions had been observed according to the Ellenberg scales. Average growing stock decreased from 417 to 405 m^3 ha^{-1}, while amount of dead wood increased from 14.0 up to 23.8 m^3 ha^{-1}. No significant differences in biotic responses were observed between control and influenced stands during 6–7 year period. At least in the short-term, suitable conditions had been preserved for the survival of epiphyte lichen, mollusc and polypore indicator species during management in neighboring stands.

LVM project: "Effect of forestry on the forest ecosystem and related ecosystem services".

P2.20

Declines of waterbirds in a boreal lake complex are explained by forest cuttings in the catchment area by increasing brownification

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Abstract

Brownification of freshwater is a global issue with many implications. The high accumulation of organic matter causing the darkening of freshwater is explained by numerous factors including climate, water quality and land use. The increasing trend in temperatures accelerates the discharge of organic matter, provoking a worsening of water quality and instability in water ecosystems. One example of this alteration can be found in the population of waterbirds (fish eaters, diving and dabbling ducks and other species) in lakes Kukkia and Rautajärvi in Finland, where the number of waterbirds has decreased by 40% since the mid-1980s. We run Linear Mixed Effects and dredging models to determine how climatic, chemical and land use factors are interacting with one another and how those interactions impact waterbird density. According to our results, forest cutting in the catchment is significantly relevant in explaining the decline of waterbirds, especially when interacting with temperature.

P2.21

Edge age impact on composition and diversity of vegetation in black alder forests growing on drained peat soils

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Abstract

Many studies have confirmed existence of mutual interaction between adjacent forest stands, however there is a lack of knowledge on how this impact changes over time. In this study we analysed the influence of adjacent forest stand's edge age (period of time since the last regeneration cut) on composition and diversity of vegetation in EU habitat 9080 *Fennoscandian deciduous swamp woods.

To achieve this, 40 m transects were established in 6 black alder forest habitats that share edge with a stand in which regeneration cut was carried out 8–18, 29–48 or ≥ 49 years ago. Transects, with 15 sampling plots (1x1m) each, were positioned perpendicularly to the border of the adjacent stand, reaching towards habitat's centre. The coverage in % was evaluated for: tree-shrub, vascular plant and moss-lichen layer, additionally the % of deadwood, bare soil, tree root flare and leaf litter were determined. The average age of alder stands, adjacent forest type and angle, that describes to what extent the centre of each sample plot is positioned towards edge, was assessed. To distinguish factors influencing vegetation diversity the Multivariate analysis of variance (MANOVA) was used. Detrended correspondence analysis (DCA) was applied to describe the main gradients in species composition regarding previously mentioned factors.

The distance from the edge and the openness to the edge, characterized by the angle, are interrelated factors – as the distance from the edge increased, the number and diversity of vegetation species in habitat decreased. Species characteristic to deciduous swamp forests were mostly detected in black alder habitats which had a shared forest edge with younger adjacent stands, thus habitats that had older edges exhibited pronounced presence of species associated to other forest types. After ≥ 49 years post management in adjacent forest stand the overall diversity of vegetation species in habitat was the highest.

P2.22

Modeling the management of drained peatlands using selective forest harvesting and rewetting in Finland

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Abstract

Forested peatlands are widely utilized in Finland; approximately 5 million hectares were drained for forestry in mid-1900s, and today more than 20% of forest growth and wood harvesting takes place in peatland forests. Drained peatlands are considered to have significant climate change mitigation potential, as the peat soil under low soil water level conditions loses carbon to atmosphere due to enhanced decomposition. On the other hand, methane production and emissions increase when the soil water level is high. Here we studied two alternative peatland forest management options. Peatland rewetting is expected to create a long-term removal and storage of atmospheric carbon in the accumulating peat. On the other hand, for peatland forests remaining in production it has been suggested that transpiration from trees could be regulated to maintain the soil water table at a level reducing soil emissions but sustaining tree growth without further drainage operations. The required amount of transpiration could be controlled by selective harvesting of trees. It is necessary to study GHG responses under different management options. Here we use two ecosystem process models (JSBACH-HIMMELI, LDNDC) to create carbon dioxide and methane projections for Finnish drained peatlands for future decades. The management options include restoration, selective harvesting, clearcutting and reforestation of peatlands. We will investigate the development of GHG sinks and sources, and changes in biophysical variables such as soil moisture, water table and albedo, and estimate the changes in radiative forcing.

P2.23

Soil respiration in rewetted boreal peatlands – towards natural levels?

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Abstract

Peatland restoration starts with rewetting by blocking ditches. Successfull rewetting is anticipated to start restoration process towards the conditions of natural peatland. One of the major processes, affected by drainage and restoration, is soil respiration (Rsoil), which is a sum of respiration by heterotrophic (Rh) and autotrophic (Ra) organisms. Drainage increases the both components of Rsoil, through the increases in soil organic matter and litter decomposition and through increased tree root respiration. Increased Rhet in drained peatlands typically leads to the loss of soil C to the atmosphere. Successfull rewetting is expected to restore anoxic conditions and thus decrease Rhet and soil C loss. How good the Rsoil restoration success been in boreal drained peatland forests, is still inadequately known.

We measured total Rsoil and Rhet in 27 rewetted and 6 natural, fertile peatland forests in Southern and Middle Finland in 2021–2023. The rewetted sites were 1 to 28 years old. We used the closed chamber method with portable gas analyzers. Rhet was separated from total Rsoil by cutting roots and above ground vegetation from the plot. Fluxes were measured bi-weekly-monthly 17–18 times during 7/2021 to 3/2023. We will compare Rsoil in natural, drained and rewetted peatlands using this new material and old published data from Finnish peatlands, mainly of our own research group.

We hypothesize to see a decrease of Rsoil in time after rewetting from drained towards natural conditions. We expect to see faster decrease in sites where rewetting has been more successfull, i.e. WT has risen faster and higher. We also expect to see higher seasonal Rsoil dynamics in rewetted than in natural peatlands, as WT dynamics appears to be higher in rewetted than in natural mires.

P2.24

The effect of afforestation on soil respiration and methane flux at cutaway peatlands

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Abstract

In Finland, afforestation has been the main after-use for cutaway peatlands, but only a few studies have been conducted on the climate impacts of afforestation. Here, we studied the effect of afforestation on soil carbon dioxide (CO_2) and methane (CH_4) fluxes, litterfall and vegetation C stocks at cutaway peatlands.

The study was conducted at five cutaway peatlands in Central Finland in 2021–2022. CO_2 and CH_4 fluxes were measured with closed chambers from 14 sample plots, along with measurements of water table level (WT) soil temperatures, above ground litterfall, and tree stand C stocks. CO_2 efflux was measured from vegetated and unvegetated points to separate total (Rtot) and heterotrophic (Rhet) respiration. Forest stand age varied from 0–57 years and peat layer thickness from 10 to over 100 cm.

The instantaneous Rtot and Rhet varied between -39 and 1662 mg m^{-2} h^{-1} and -39 and 836 mg m^{-2} h^{-1}, respectively (2021 data). Soil temperature and forest stand age correlated positively and peat layer thickness negatively with soil respiration. WT did not have significant effect on soil respiration.

The instantaneous CH_4 fluxes from the vegetated points varied between -0.15 and 1.21 mg m^{-2} h^{-1} (2021 data). Forest stand age and peat layer thickness correlated with CH_4 flux, whereas WT did not. Non-afforested sample plots acted as methane sources and the sample plots with the more mature forest acted as methane sinks.

Based on this study, afforestation increases soil respiration and decreases methane emissions. However, the suitability of afforestation as an after-use method based on greenhouse gas emissions cannot be concluded based only on these results. Ecosystem level results with litterfall and changes in vegetation C stocks will be amended to the results, to estimate the climate impact of afforestation.

P2.25

Impacts of partial harvest and clearcut on methane and nitrous oxide emissions of forestry-drained boreal peatlands

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Abstract

Drainage can cause large greenhouse gas emissions from peat soils. While the effect of water table (WT) depth on these emissions at peatlands with developing forests has been extensively studied, the impacts of tree stand cuttings have received little attention so far.

We measured methane and nitrous oxide emissions from soil during several years following various types of cuttings in peatland forests in Finland. The data include two sites with thinning from below, two sites with overstorey harvesting, two sites with selective thinning from above, four sites with small-gap harvesting, and five sites with clearcut. All the sites had uncut plots as control treatment.

Changes in WT depth varied depending on harvesting intensity, and this was an important control of methane emissions. If WT rose high enough, soils turned into methane sources. On the other hand, even a considerable WT rise did not necessarily cause methane emissions if water table stayed well below soil surface.

The effect of cuttings on nitrous oxide emissions was not clearly controlled by the WT depth. Instead, nitrous oxide emissions likely result from the excess nitrogen due to release from logging residues and dying ground vegetation and decreased nitrogen uptake by living vegetation.

In the presentation, we discuss the longevity of the impacts of cuttings and suggest emissions factors for the various cutting methods.

P2.26

Differences in reflective responses of Finnish forested peatlands over time depending on their depth

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Abstract

Organic soils are a significant source of greenhouse gases. Over 70% of Finland is covered by forests, of which approximately one third is located on peatlands. In the past, Finnish peatlands have been drained for forestry and agricultural activities, which has turned the drained peatlands to carbon sources. Forested peatlands can be restored by filling drainage ditches, but the effects of restoration on the carbon cycle depend on several factors, such as nutrient levels in soil and productivity of tree growth, emphasizing the need for throughout knowledge on peatland status over time. In the project 'Peat knowledge on agricultural lands', a nation-wide peat depth estimate was calculated with two different machine-learning approaches. First, a Random Forest classifier was used to separate peatlands from mineral soils. Then, the national peat depth estimate was modelled with both Gaussian Process Regression (GPR) and Geographically Weighted Regression (GWR) methods. Based on the results of both modelling methods, we used Earth Observation Data Information Extractor (EODIE) toolkit to calculate the average peat depth estimate for forested peatland patches extracted from CORINE Land Cover 2018 dataset. Finally, we compare the reflective responses of Finnish forested peatlands with different estimated peat depths in satellite observations, both in the optical (Sentinel-2) and Synthetic Aperture Radar (Sentinel-1) domain by extracting forest-patch level multiyear time series data with EODIE. We aim to find differences in responses from areas with varying peat depths especially during or after heavy rainfall or drought periods that are determined from gridded daily meteorological data with 1 km spatial resolution provided by the Finnish Meteorological Institute. The findings have potential to give complementary information for decision-making on restoration activities on Finnish forested peatlands in accordance with the Biodiversity Strategy of the European Union.

P2.27

Effects of forest management on drained peatland forests and their bacterial and fungal communities

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Abstract

Drainage has been practiced for forestry purposes in boreal peatlands for several decades. Forest management and drainage affect the water table level, organic matter quality, soil chemical properties, and oxygen availability. These factors are significant when concerning soil microbial communities. Microbes are responsible for soil carbon and nutrient cycling, and thus understanding the effects of forest management on microbes is crucial for successful and sustainable forestry. We studied the responses of bacterial and fungal communities to forest management and seasonality in a drained experimental peatland site consisting of a clear-cut forest, continuous cover forest (CCF), and uncut control forest. We used bacterial 16S and fungal ITS2 RNA analysis to discover the present active microbial community members. The hypothesis was that the bacterial and fungal communities differ between the forest management types and that the microbial diversity and community composition in CCF and control forest resemble each other, whereas the clear-cut differs from the other two. Furthermore, we performed our study over a single growing season in order to assess the potential seasonality in the microbial community composition. Generally, we found no dissimilarities in bacterial or fungal diversity or species richness between the forest management types. However, as we hypothesized, the soil microbial communities were more alike between the CCF and control forest than between the clear-cut and control. The most common phyla in bacteria were Proteobacteria, Acidobacteriota, and Actinobacteriota, and in fungi Basidiomycota and Ascomycota. The bacteria were less prone to different forest management options and the season on the phylum level, but the differences were more visible in the rare bacterial genera, whereas in fungi the dominant phyla differed both seasonally and based on management. Additionally, the fungal communities were affected by the summertime drought experienced in the study area.

P2.28

Above-ground biomass allocation in boreal drained Downy birch (*Betula pubescens* Ehrh.) dominated peatland sites

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Abstract

Stand biomass in boreal forests plays a crucial role in carbon cycling. In this study, we examined the effect of stand age on above-ground biomass allocation in downy birch (Betula pubescens Ehrh.) in three drained peatland sites in Central Finland. We used allometric equations to estimate individual-tree above-ground biomass and its various components, including stem wood, stem bark, living branches, leaves, and dead branches. The above-ground biomass ranged from 9.2 t ha^{-1} to 276.0 t ha^{-1} and foliage biomass from 0.008 t ha^{-1} to 0.6 t ha^{-1}. We found that stand age had a strong correlation with above-ground biomass, but foliage biomass appeared to peak at the middle-age (50 years) stand compared to the young (10 years) or mature (80 years) stands. Our findings improve our understanding of how biomass allocation patterns change over time, specifically the changes in foliar biomass, and its impact on litter inputs into the soil.

P2.29

Windthrow effect on soil greenhouse gases emissions, organic carbon pool and microbial community of drained peatland forest

Qian Li, Mikko Peltoniemi, Bartosz Adamczyk, Anne Tyvijärvi, Sylwia Adamczyk, Boris Tupek, Aleksi Lehtonen, Raisa Mäkipää

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Abstract

Storms and windthrows cause severe damage in boreal forest and their frequency is expected to increase due to climate change. The carbon (C) stock and C sink of stand biomass are reduced after such disturbance. Forest soil contains more C than trees while its response to disturbances was less studied. To examine how soil C stock, greenhouse gas (GHG) emissions and microbial community are affected by disturbances, experiments were conducted in a drained peatland forest site in southern Finland. Treatments were established in September 2021: (1) 20 cm depth topsoil was removed (2 x 1 m) to simulate the effects of uplifting surface soil by uprooted trees; (2) soil surface (2 x 1 m) was covered by residuals (50 kg branches with needles) to simulate the excess nutrient input to soil by the canopy of felling trees; (3) undisturbed control. The GHG (CO_2, CH_4 and N_2O) fluxes were measured throughout the snow-free period. After one year, the 0-10 cm soil were sampled from two disturbed treatments, the 0-10 cm and 20-30 cm soil were sampled from control plots to analyze inorganic nitrogen, stable and labile soil organic carbon (SOC) pool, tannins, fungal biomass and necromass, and enzyme activities. In the first year after treatment, CO_2 emissions from topsoil removed plots decreased. The CH_4 sink also declined, even switched to CH_4 source when WT was high, indicating the role of surface soil and its microbes on regulating GHG emissions. The CO_2 and N_2O emissions increased with residual cover, suggesting the nitrogen input and microclimate change affecting soil microbial processes. The ergosterol (fungal biomass marker) decreased under both treatments compared with control. We found a fast response of GHG emissions and microbial community to disturbances, which also could lead to a change of soil C stock.

P2.30

Co-designing Holistic Forest-based Policy Pathways for Climate Change Mitigation

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Abstract

To achieve the goals of the Paris Agreement, the EU set ambitious targets to reduce GHG emissions by at least 55% in 2030 and to become climate neutral by 2050. This requires societal and economic reforms, and new and additional GHG reduction efforts within all sectors. Forests and forestry play an essential role in this context as they provide carbon sinks and their products can substitute for emissions-intensive materials, thereby reducing emissions. However, forest carbon sinks are non-permanent and threatened by human interference (deforestation, degradation), as well as by climate change facilitating natural disturbances. Simultaneously, the EU strives to protect nature and reverse the degradation of ecosystems and biodiversity loss, which is threatened by forest use. Moreover, climate change and poorly implemented mitigation measures might negatively impact other (forest) ecosystem services, in particular biodiversity, calling for solutions, which account for potentially diverging targets.

Within this context, the ForestPaths project will co-design, quantify and evaluate holistic forest-based policy pathways to optimize the contribution of forests and the forest-based sector to climate change mitigation, while considering adaptation needs, biodiversity conservation, and forest ecosystem services provisioning. ForestPaths will improve the understanding of factors shaping decision making by forest practitioners and provide information about Climate & Biodiversity-Smart (CBS) forest management options across Europe, alongside developing improved forest monitoring methods and modelling tools. The project engages with policymakers, forest practitioners, forest-based sector, and several other stakeholder groups in a co-design process to develop policy pathways. Effects of forest-based mitigation, and the trade-offs and co-benefits of policy pathways will be evaluated with a next-generation integrated modelling framework. Results of the project will be presented in an online policy support platform. Here, we present the conceptual approach of the project for informing the research community and stakeholders about the project and the expected results and impacts.

P2.31

Evaluating Two Decades (2000-2020) of Nordic Forest Policy: Based on Expert Interviews

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Abstract

Robust, comprehensive, and legitimate evidence-based policymaking is increasingly called upon to tackle present and future sustainability challenges, including the management and governance of Nordic Forest systems. This study uses interviews with key informants to unveil changes in forest policy implemented in Sweden, Finland, Norway, and Denmark between 2000 and 2020, with further regards onto 2023. We focus on identifying and evaluating policies and their outcomes related to forest products, biodiversity, carbon budget and other ecosystem services or socio-economic issues. We further discuss what do such developments imply for present and future matters of forest management and governance, as well as stakeholder engagement. The study is an in-progress analysis, and it is part of an interdisciplinary project titled 'Green forests policies: a comparative assessment of outcomes and trade-offs across Fenno-Scandinavia' (GreenPole), which aims at performing a comparative analysis of forest policies and governance approaches in the Nordic countries during the past two decades using mixed qualitative and quantitative methods.

P2.32

Managing urban forests: a case study from Helsinki in winter 2023

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Abstract

Managing urban areas needs to be done in interaction with citizens and stakeholders. When planning the operations, interviewing, and informing is crucial. Knowledge of climate law, neighborhood law, expertise in forests and tree health are needed. In the operations careful use of technology, assessment of landscape vulnerability and risk, impacts of weather and climate on soil conditions and biomass future play an important role.

In Helsinki, mitigation and adaptation to climate change are actions that sometimes are in conflict especially as regards building and construction, urban forest management, recreation areas and health. Here we present a case from winter 2022–2023 when a small park in Helsinki was managed nearly 30 years after the last treatment. The neighbors were consulted several times and one of them was the focal point in informing others. The park trees in the border zone were according to the law the most obligatory ones to be harvested. Sick and violated trees in the park elsewhere were also planned to be removed. There were 15-17 trees on the preliminary list. Also, a safe route respecting historical remnants of World War I to collect the tree material with the machine had to be planned.

We will present practical and scientific findings based on the case and actions taken. For instance, a comparison with Sentinel-2 NDVI is made from before and after the management plan and actions.

P2.33

Tree regeneration in urban spruce forests is shaped by management history

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Abstract

With projected climate change, urban spruce-dominated forests are facing increasing risks of pest and weather-related forest damages, encouraging management for mixed stand structures. In the major cities of southern Finland, forests are preferentially maintained continuously covered, and tree regenerations is mostly reliant on naturally emerging sapling stock. To understand the role of forest management in shaping natural tree regeneration in urban forests, we studied the occurrence and abundance of tree saplings in spruce-dominated tree stands on a management continuum ranging from partially logged to undisturbed near-natural stands. Study sites (N = 74) were located in three urban centers in southern Finland: Tampere, Lahti and Helsinki region. We analyzed the data by comparing tree regeneration potential between management classes reflecting logging intensity, and by relating the occurrence of saplings with current structures of the living tree stand.

Compared to undisturbed stands, partially logged sites had increased regeneration of broad-leaved trees and repressed regeneration of spruce, while the most abundant sapling tree species across all management classes was rowan. We conclude that partial logging can be a successful way of directing tree regeneration towards lower dominance of spruce. However, when the canopy is only partially opened, created gaps may end up being filled primarily by rowans that tolerate shade comparatively well. Because the ingrowth of rowan and many other broad-leaved tree species is strongly restricted by dense populations of large browsing animals in non-urban areas, urban forests may develop stand structures and tree species composition that are otherwise rare in the Fennoscandian boreal forests.

P3.1

Effect of topography on tree radial growth, vegetation structure, richness and composition in a human-impacted mountain in Northwestern Yunnan, China

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Abstract

Elevation-for-latitude research offers a tool for studying vegetation structure and composition under changing climate. Understanding how elevation, aspect and slope influence vegetation patterns could help explain the effects of changing temperature and precipitation on vegetation. However, over 63% ecological studies have been carried out in protected area, which occupy only 13% of ice-free terristrial ecosystem. The more human influenced area are largely understudied. Here, we chose a human-influenced mountain with more than 2200 m elevational differences from 1900m to 4200 m in Hengduan mountains in Eastern Himalaya, Southwestern China. Forest type ranged from temperate forests, boreal forest, and alpine grasslands and shrublands. We set plots at 100m elevation interval along transects running to four due direction from the peak. We quantified how tree radial growth, maximum height, basal area, above-ground biomass, tree and shrub species richness, and woody species composition changed with elevation, aspect and slope. Meanwhile, we also detected how tree radial growth changed with microclimate conditions, and how they responsed to historical extreme climate events. Our results of tree growth and vegetation pattern in a human-impacted mountain landscape could be used as a baseline for predicting plant shifting under climate change, and the concurrent results of tree size and above ground biomass can be applied to designing forest management regimes.

P3.2

Conceptualizing structural uniqueness of trees using terrestrial laser scanning

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Abstract

We aim at investigating whether trees feature a unique structure that distinguishes each tree individual from one another. The study builds on a theory suggesting that forest ecosystems harbour a variety of sites for trees to grow, with no site being similar to others. Even within the same geographical region and similar soil and climatic conditions, competition between individuals eventually regulates the availability of growth resources such as sunlight, nutrients, and water. Tree clones sharing the same genotype and growing at a close proximity will have different phenotypes due to their individual interaction to the environment. This suggests that each tree should have a unique structure that is characterized by the dimensions and shape of the main stem as well as the distribution and orientation of branches. However, detailed observations of the tree structure are needed to confirm the concept of tree structural uniqueness. Terrestrial laser scanning (TLS) allows three-dimensional reconstruction of objects of interest at a millimeter-level of accuracy, being a feasible tool to characterise trees non-destructively. We hypothesize that by using state-of-the-art TLS technology it is possible to characterize the phenotypes of trees at such geometric accuracy that enables identification of tree individuals by their structure. We explore the concept of tree structural uniqueness by using an experimental setup including 100+ Scots pine (*Pinus sylvestris* L.) trees having seemingly similar growing conditions in a managed boreal forest stand. For each tree, TLS is used to characterize stem form and branching structure that are used as the distinguishing features to reliably identify trees from one another in time and space. The study contributes by showing that TLS could be used to characterize tree structural uniqueness, highlighting the possibility of using the methodology in applications requiring information of tree origin.

P3.3

Enhancing drone-based tree interpretation with local field measurements

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Abstract

There is currently a great interest in using drones for forest inventory purposes. Currently, drone-based inventories are relatively expensive because plenty of supportive field measurements are needed for model construction, and the inventory areas are typically small. One proposed solution is transferring previously constructed models to a new inventory area and calibrating them with a small amount of local field measurements.

Our objective was to compare the calibration of existing models and construction of new models to determine which approach should be preferred in drone-based forest inventories. Our material included field measurements and drone-based laser scanning data, from which individual trees were automatically identified.

A general mixed-effects model for diameter at breast height (DBH) had been formulated earlier based on data from a geographically wider area. It was calibrated to the survey area with the field measurements of 2–10 randomly selected calibration trees. The calibrated diameters were used to calculate the diameter of a basal area median tree, tree-level volumes and the total volume of all trees. The estimates were compared with field measured values. Second, new DBH-models from the survey area were formulated based on 2–10 randomly selected trees and calibrated similarly as in the first phase. Third, plot-specific height-diameter regression models were formulated by selecting randomly ten trees from each plot.

Calibration reduced the prediction errors of all variables and an increase in the number of calibration trees improved the predictions in a logical manner. The calibrated predictions from the existing mixed-effects model were very similar to the separately formulated mixed-effects models and plot-specific regression models.

We conclude that measuring a small number of calibration trees can provide a sufficient accuracy with minor effort in additional in-situ field measurements and reduce the needed number of field measurements in comparison to traditional inventory methods.

P3.4

Carbon stocks in soil and vegetation a decade after clearcutting: influence of soil disturbance by site preparation and stump harvesting

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Abstract

We examined the hypothesis that soil disturbance by site preparation or stump harvest reduce carbon stocks in soils and vegetation at the decadal time scale following clear-felling of coniferous forest, compared to management with no site preparation or stump harvest.

Three field experiments in different climate regions of Sweden were studied, each with a randomized block design (n=4). Following clear-felling and harvest of stems and logging residues, the treatments were: control, i.e., no site preparation (0), disc harrowing (DH), patch scarification (PS), and stump-harvesting (SH). Carbon (C) and nitrogen (N) stocks in soil, and biomass and C stocks in ground vegetation and trees of all species were measured about 10 years after clear-felling.

Soil C and N stocks were estimated from coring of the humus layer and the mineral soil (0–20 cm). Biomass and carbon stocks in aboveground vegetation was estimated by destructive sampling. Biomass and carbon stocks in tree and bush-layer was estimated from biomass functions for Pinus sylvestris, Picea abies, Betula spp., Sorbus aucuparia, and Salix caprea, based on allometric relationship between biomass and stem diameter at root collar and breast height, and tree height. The results are discussed in relation to degree of soil disturbance.

P3.5

The effect of shelterwood method and plant stock type on growth and foliar nutritional status of pine regeneration

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Abstract

The current trends in forest management of Northern Europe are following the society's expectation to find alternative forest regeneration systems to clear-cut based forestry. Shelterwood methods are considered to be a promising alternative to clearfelling. However, there is lack of empirical knowledge about longer observations (> 10 years) of regeneration performance under different shelterwood systems. We analyzed height growth and foliage nutritional status of Scots pine seedlings under three different shelterwood methods (uniform shelterwood system with 160 overstorey trees ha^{-1}, shelterwood strip felling with the width of 30 m, and shelterwood group selection with the gap diameter of 35 m) and with four regeneration types (natural regeneration by seeds, artificial sowing, bare-rooted and containerized transplants), based on the repeated measurements in 11 consecutive years. Seed-based regeneration showed 17–34% lower height growth compared to planted trees in all the shelterwood methods. The highest growth was observed for planted seedlings in strip felling treatment, which was similar to pine regeneration growth in clear-cut sites on a similar soil. The slowest height growth was observed for uniform method where the height was 41% (planted trees) and 51% (seed-based regeneration) lower than in the strip method. Foliar nitrogen concentration of regeneration trees was significantly lower in uniform method than the other shelterwood methods for both planted and seed-based regeneration. Slower height growth and nitrogen deficiency in the uniform method is explainable by the root competition with old overstorey trees. To conclude, uniform shelterwood method causes a 4–5-year lag in regeneration height growth in comparison with the strip felling method or clear-felling during the first 11 years. Complimentary planting can advance the success of shelterwood method by 2–3 years in comparison with seed-based regeneration. This research is conducted under European Commission's Horizon 2020 programme under grant agreement No 101000406 (project ONEforest).

P3.6

Vegetation response to forest road and ditch reconstruction: a case study from hemi-boreal forests

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Abstract

Linear forest infrastructure objects constructed primarily to increase the efficiency of management are significant forest landscape features. While roads and ditches are important for forest ecosystem service provision, they may cause significant changes in plant species composition, and it is important to assess the extent of this change. We monitored changes in plant species composition along two types of reconstructed linear infrastructure objects, recording vegetation on four reconstructed roads and four ditches (two reconstructed, two old ditches) each summer from 2016 till 2020. In addition, in 2022 one less managed forest road was selected to represent less intense managed road. The total number of species and cover of species were recorded along a one km long section in 10 3x1 m large plots on both sides on each chosen object, resulting in 20 plots in each object. Reconstructed roads and ditches significantly change number of species and their composition along managed objects. Reconstructed linear infrastructure objects have higher species diversity with more nutrient- and light-demanding species. Roads promote distribution of vascular species uncharacteristic to forests, including potentially invasive alien species. The monitoring results showed increasing distribution of two potentially invasive species in Latvia - *Solidago canadensis* and *Lupinus polyphyllus* along forest roads.

P3.7

The impact of uniform shelterwood cutting on understory vegetation in Scots pine forests during a decade

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Abstract

Shelterwood cutting (SW) is generally considered less destructive forest regeneration method for biodiversity than clear-cutting. However, the direct effects of SW may vary, depending on the SW method, soil type, studied species group and time after cutting. We analyzed the changes in vascular plant and bryophyte communities of Scots pine (Pinus sylvestris) forests during 10 years after uniform SW, using the data from permanent vegetation plots. Seven stands located on dry to moderately moist mineral soil in south-eastern Estonia were chosen and 12–15 vegetation plots (size 1 m^2) were established prior to harvest in each stand. The inventories of vascular plant and bryophyte layers on plots (N = 96) were carried out 1) before SW (2012, 2013), 2) in the first summer after cutting (2013, 2014), 3) 3–4 years after cutting (2016), and 4) 9–10 years after the first cutting (2022). In three stands the second shelterwood cutting was carried out in 2019-2021. The overall species richness of vascular plant and bryophyte layers increased after SW due to the addition of pioneer species. By 9–10 years after cutting a few short-living species that were recorded 3–4 years after cutting had already disappeared. However, the average per plot richness of vascular plants and bryophytes was still considerably higher than prior to harvest. The cover of bilberry (*Vaccinium myrtillus*) and lingonberry (*V. vitis-idaea*) dropped after cutting and soil scarification but recovered in time. As the cover of bilberry and lingonberry was significantly higher 9–10 years after harvest than prior SW, we conclude that SW is a sustainable method for forest berries. Late-successional forest orchid Goodyera repens was found in five stands prior to harvest and in three stands 9–10 years after cutting. Maintaining undisturbed bryophyte layer and avoiding overburdening with cutting residues are necessary for the survival of Goodyera repens in SW.

P3.8

Productivity of Norway spruce and silver birch in monocultures and mixture on abandoned agricultural land

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Abstract

Replacing monocultures with mixed forests is considered to improve ecosystem's resilience and carbon uptake capacity under changing climate. As a broad generalization, mixed forests are expected to overyield monocultures of the same species. A growth and yield study was done in 18-year-old Norway spruce (*Picea abies* (L.) H.Karst.) and silver birch (*Betula pendula* Roth) monocultures and a 50/50 mixture of both species in hemiboreal Estonia. The growth and yield data were collected from ten replicated study plots in both monocultures and mixture. Silver birch benefited from growing in the mixture, as the average single tree stem volume was 120% of a single tree stem volume in monoculture. Norway spruce suffered from the interspecific competition in the mixture as the average single tree stem volume for spruce in the mixture was 39% of stem volume in monoculture. The most productive forest type by stem volume was the spruce monoculture, yielding 132% of birch monoculture and 139% of the mixture, with CAIs being 24.4, 14.3 and 18.8 m^3 ha^{-1} $year^{-1}$, respectively. Birch monoculture overyielded the mixture by 106%. The establishment of birch-spruce mixture will suppress the growth of spruce at early stages due to increased competition for resources on spruce. The present study does not support the generalization of mixture overyielding in comparison with monocultures with the example of Norway spruce and silver birch at current stand age. Moreover, higher growth of monocultures means that they have higher climate benefit through higher carbon sequestration to standing biomass. Even though losing in productivity to both of the monocultures, planting a mixture of the species creates a more heterogenous forest structure which should favor biodiversity and improve forest ecosystem's resilience to climate change. This research is conducted under European Commission's Horizon 2020 programme under grant agreement No 101000406 (project ONEforest).

P3.9

Sustainable forest management – phytoremediation and biomass production potential of hybrid aspen plantations

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Abstract

Heavy metals pose a high environmental risk as elements are undestroyable and the most of them have toxic effects on living organisms when exceeding a certain threshold concentration (such as As, Cd, Pb, Hg). Fast-growing Populus spp. trees are considered as potential tree species for the absorption, accumulation, storage and degradation of environmental pollutants, such as heavy metals. One of the most planted tree Populus spp in Northern Europe is hybrid aspen (Populus tremula L. × P. tremuloides Michx.). Hybrid aspen is mainly planted for short-rotation forestry on abandoned agricultural lands, but the species has a great potential for ecosystem recovery and phytoremediation on contaminated industrial landscapes. The aim of the study is to assess the dynamics and interactions of heavy metals (Mn, Cu, Pb, Zn, Cd, Cr, Co, Fe, Mo, Ni, As) in plant-soil system of hybrid aspen plantations on post-mined oil shale quarries and in polluted industrial area at the end of the potential rotation cycle (+20 years). For comparison with polluted areas in North-East Estonia, heavy metals (mainly As, Hg, Pb, Cd, Fe) accumulation in the woody biomass and in soil was assessed in hybrid aspen plantation in the region with low industrial pollution. Hybrid aspen showed a great potential for phytoremediation of heavy metals in contaminated industrial areas in comparison with other used tree species (Pinus sylvestris) according to the literature review due to higher growth speed. The findings will help to understand the changes in the system tree-soil growth environment and prognosticate possibilities of using hybrid aspen for afforestation of former oil shale mining areas for ecosystem recovery. This research is supported by the Estonian Research Council grant PRG1007 and European Commission's Horizon 2020 programme under grant agreement No 101000406 (project ONEforest).

P3.10

The structural diversity of European beech stands at the northeastern edge of the distribution range

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Abstract

Due to climate change, expansion on the northeastern border of European beech (currently in Latvia) is projected, especially in the case of assisted migration. The growing conditions in the marginal populations are more restrictive, therefore it is important to gain knowledge about stand structure and possible differences in core populations.

Beech was introduced in Latvia in the middle of the 19th century and became naturalized in the 20th century. The study was conducted in five forest stands in Latvia located outside the current beech distribution range. The analyzed trees were second-generation trees, propagated from the first-generation tree seeds that had been introduced from Germany. In each of the stands, two sample plots (area 500m^2) were randomly established. The dimensions of living trees from the canopy layer (height, diameter at breast height) were evaluated in the plot. Visual assessment of beech stem quality traits having ecological as well as economic importance was detected - the presence of a ramicorn branch, forking, cracks, epicormic shoots, and height of the lowest living and dead branches. Indices quantifying spatial structure (tree aggregation, diameter differentiation, species mingling index) were calculated.

Although the beech stands were planted, the tree aggregation indices were intermediate, indicating that natural structures are formed as a result of small-scale disturbances. The results of our study give insight into beech structure in second-generation forest stands. Overall beech demonstrates a good potential input to forestry as the dimensions of the trees were sufficient for wood manufacturing. Although wood quality decreasing traits were often detected, this increases the contribution of microhabitats, therefore biological diversity.

P3.11

Vegetation comparison for different forest management approaches in Norway spruce stands in Latvia

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Abstract

Norway spruce is one of the most widespread and economically important tree species in Europe. However, recent potential range and dynamic vegetation models indicate that with climate change and limited adaptation measures Norway spruce will decline, with severe economic and ecological consequences. Compared to natural or old-growth forests, nowadays forest ecosystem biodiversity has decreased due to the reduction of specific habitats, therefore it is important to understand how management regimes can be changed to integrate biodiversity components in managed forests as well.

This study aimed to evaluate and compare the understory vegetation and its affecting factors in unmanaged (7 stands), old (9 stands), and plantation spruce stands (4 stands). In each of the stands, four circular plots (500m^2) were established with three 1x1m sized plots placed in each cardinal direction. The diameter and height of all the trees in the circular plot were measured and the percentage cover in each 1x1m sized plots was estimated. Shannon-Wiener index, Ellenberg indicator values were calculated, and DCA ordination was established.

A higher mean percentage cover of vegetation was found in plantations, although most species were characteristic of meadows. The Shannon-Wiener index showed that species diversity between management types was similar with no dominant species. Although, the composition of species differs significantly between management types. The primary determining factors being the average diameter and height of trees, spruce cross-sectional area, and leaf litter as well as edaphic factors – moisture, and nitrogen content in the soil.

P3.12

Increases in tree diameter growth by moderate thinning in coniferous stands in Korea

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Abstract

Thinning is an artificial practice, performed to enhance tree growth by decreasing competition. However, the optimal intensity of thinning remains uncertain and is the current research. This study aimed to investigate a proper thinning level by examining the tendency between thinning intensity and tree diameter growth. We measured tree diameter at breast height (DBH) in 44 temperate coniferous stands, dominated by *Chamaecyparis obtusa* and *Pinus* spp. in Korea. These stands were grouped by thinning intensity (percentage of numbers of trees removed); no thinning (0%), light thinning (0–15%), moderate thinning (15–30%), and heavy thinning (≥30%). We also used a generalized linear regression model with maximum likelihood estimation to analyze the effects of thinning intensity and stand density on DBH growth. Stands with lower density tended to have larger mean DBH. There was no significant difference in DBH between light thinning and no thinning groups, however, stands with moderate and heavy thinning intensities had larger mean DBH compared to no thinning stands. In addition, the mean DBH of moderate and heavy thinning stands was not different. DBH growth showed a positive relation with thinning intensity, and moderate thinning seemed to be the most optimum level of thinning to increase DBH growth for the study stands. Overthinning may decrease DBH growth because of rapid changes in environmental conditions. Thinning may be practiced with moderate intensity to increase tree growth with less loss of trees. This study was carried out with ´R&D Program for Forest Science Technology (Project No. 2022460B10-2324-0201)' supported by Korea Forest Service.

P3.13

UAV and handheld hyperspectral imaging promotes understanding of *Sphagnum* discrimination and distrubution

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Abstract

Sensor development facilicates accurate vegetation classification promoting the understanding of spatial distribution of species and diversity. This is interesting for peatland ecosystems, where particularly *Sphagnum* mosses pose a challenge regarding spectral separability. This study evolves around the question if and which benefits hyperspectral sensors provide over conventional RGB and multispectral sensors. We investigated hereby firstly if hyperspectral imaging under unsteady field conditions can provide reliable data for species discrimination. Secondly, we examined if hyperspectral data recorded with a handheld device can be used to establish a spectral library for image classification of *Sphagnum* mosses. Hyperspectral data was gathered from vegetation plots with a handheld device and with Unmanned Aerial Vehicle (UAV), complemented by elevation data and additional vegetation plots throughout the study area. Atmospheric and topographic correction was done with the Hylite package for python and adjusted, if needed, for vegetation application. Preliminary results show that *(Sphagnum* moss) species can be discriminated, yet, varying moisture conditions affect the spectral reflectance. The limitation of the UAV-hyperspectral data is the spatial resolution; it largely captures mixed pixels and not only pure *Sphagnum* regions, which limits the use of a spectral library for image classification when established on different, spatial scale. Our preliminary results suggest that UAV-hyperspectral imaging is useful for those sites, where *Sphagnum* carpets and lawns prevail to a great extent. They further indicate that hyperspectral data can be beneficial for peatland restoration monitoring as it gives information about drying stages.

P3.14

Effects of soil freezing on soil microorganisms and plant roots

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Abstract

Snow is a critical regulator of underground ecosystem and soil processes. Winter snow depth and duration have decreased in many areas due to the on-going global warming. So that the risk of soil frost increases when there is no snow cover to insulate the soil, which affects soil nutrients cycling. Deep and persistent snowpack keeps soil temperature above 0 °C during winter in forests, resulting in increased microbial activity and root survivorship. Soil frost affects roots vitality and microbial communities, which may have significant effects on the soil organic C and N pools. Therefore, snowpack plays a vital role in fine roots' growth and mortality, as well as in root-microbe interactions. Moreover, root morphology is the most important characteristic to assess plant root growth, such as root diameter, root length, and root surface area. But the effects of decreased snowpack on root morphology are not clear.

This study aims to assess how removed snowpack affects pine and ericoid dwarf shrub roots growth and how soil nutrient and microorganisms respond to snow removal. The experiment consists of two treatments: control site with intact snow cover, where snow is allowed to accumulate and melt naturally, and snowless site with snow exclusion from the soil surface with shelters. Scots pine's (*Pinus sylvestris* L.) fine roots, rhizosphere soil and bulk soil were collected after two winters during 2020-2022. Moreover, the roots of ericoid dwarf shrub Vaccinium myrtillus were collected to evaluate the microbial interaction with pine roots. Soil carbon, soil nitrogen and soil respiration were measured to access nutrient cycling. To study changes in microbial response, soil microbial biomass, soil and roots' fungal community structures were measured. At the end, fine roots morphology was determined to evaluate root growth patterns.

Preliminary results will be presented in the poster.

P3.15

Spectral characteristics of tree stem bark

Jussi Juola, Aarne Hovi, Miina Rautiainen

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Abstract

Spectral libraries are essential in building a comprehensive understanding of the spectral diversity of forests. Information about the spectral properties of different canopy elements is needed in remote sensing applications and in, for example, biodiversity or land surface modeling studies. The woody material of forest canopies has a significant effect on the total forest reflectance and on the interpretation of remotely sensed data, yet research on the spectral properties of bark has been limited. To bridge this gap in research related to forests, remote sensing, and reflectance modeling, we developed set-ups that utilize a portable hyperspectral camera (Specim IQ, 400–1000 nm) in two different measurement settings. The first set-up was used to collect multiangular stem bark reflectance spectra of three common boreal tree species in a controlled laboratory setting, and the second was used to measure stem bark reflectance of ten boreal and temperate tree species directly in the forest. Spectral analysis revealed that the mean bark spectra of the boreal and temperate tree species were similar in the visible (400–700 nm) region and the interspecific variation was largest in the near-infrared (700–1000 nm) region. In addition, the intraspecific variation of bark spectra was high for all studied species from the visible to the near-infrared region (400–1000 nm). We observed significant angular effects for the three boreal tree species when the stem bark samples were measured along the principal plane. We also found spatial variation of reflectance along the tree height and different sides of the stem (north and sound). Our hyperspectral reflectance images revealed that the distributions of per-pixel reflectance values within the images were species-specific. Finally, we demonstrated that there is potential to identify common boreal and temperate tree species based on their stem bark spectra and texture.

P3.16

Evaluating tree stem form in continuous-cover and even-aged Norway spruce stands

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Abstract

In Nordic countries even-aged forest management has been the dominant silvicultural practice. Due to the effects of biodiversity loss and climate change to forest ecosystem reassessments to the forest management practices is needed. Ecosystem-based forest management systems have been proposed as alternatives, or complementary practices to the intensive, even-aged forestry. Continuous-cover forestry is one of the most promising practices in the ecosystem-based forest management toolbox. The research of continuous-cover forests has been lacking especially from the point-of-view of tree characteristics and wood properties.

Tree stem modelling is an important part of forest growth and yield, and it is widely used e.g., in forest growth calculations, forest management planning and forest carbon balance calculations. Stem taper functions are used to get precise picture of tree stem and to examine e.g., stem form. In our research we evaluated how continuous-cover forest management affected mature tree stems in contrast with even-aged Norway spruce (*Picea Abies* (L.) H. Karst.) stands. We approached the stem taper modelling with terrestrial laser scanning (TLS) data, to get precise single tree data and to study if there is need to re-parametrize most used stem taper function in Finland (Laasasenaho 1982). As the stem taper function established by Laasasenaho (1982) is based on Finland National Forest Inventory data from 1970s.

Our preliminary results showed that there was no statistically significant difference in stem taper and form of the mature trees between the continuous-cover and even-aged forests examined here. Also the taper function parameters established by Laasasenaho (1982) were valid and no significant improvement to taper and volume calculations was gained through reparametrize model to continuous-cover management stands. Tree canopy position (canopy class) on the other hand had significant effect on the tree form factor in both management practices.

P3.17

TLS-based forest canopy structure measurements across Europe

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Abstract

Satellite remote sensing provides high frequency observations of forests, allowing timely and cost-effective monitoring applications. The spatial resolution, typically in the range of tens of meters, means that forest variables need to be indirectly estimated from a remotely sensed signal. Physically-based models aim at decomposing the remotely sensed signal from forests into distinct drivers that may be used to directly characterize forests, or related to other variables of interest.

Forest structural parameters, such as canopy cover, leaf area index and clumping index, are key drivers of the remotely sensed signal of a forest. These parameters can be difficult to measure in the field. Direct measurements, apart from laborious destructive measurements and time-consuming litterfall traps have so far been lacking. In addition, modeling the reflected signal of forest canopies requires not only information about canopy structure but also about directional light transmittance through the canopy.

To address this issue, we present a method to quantify forest canopy structure and transmittance using TLS data. We measured voxelized leaf area density of forest canopies, along with directional transmittance, in 38 plots across Finland, Estonia, and Czechia. We show that a high degree of spatial detail can be very useful for research, but aggregation of canopy structure to stand level is required by most remote sensing applications. A common approach is to summarize canopy structure using leaf area index and clumping index. We introduce a new measure of forest canopy structure; the stand-level silhouette to total area ratio (STAR). Based on the commonly used shoot STAR, the stand-level STAR quantifies the influence of forest canopy structure on the reflected remotely sensed signal. We found that, from a remote sensing viewpoint, there are a number of forest canopy structures that look very different but have a very similar remotely sensed signal.

P3.18

Tree mortality detection using high-resolution satellite imagery and deep learning

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Abstract

Global change during the Anthropocene has led to climatic instability resulting in widespread tree mortality due to increasing occurrence of intensive and frequent droughts, massive outbreaks of bark beetles and forest fires and storms. Currently, we lack up-to-date information on the extent and severity of tree mortality events, which limits our understanding and mitigation actions of the effects of climate change on forests. Efficient tree mortality mapping and monitoring methods are urgently required for supporting sustainable use of forest resources and for assessing the risk of tree mortality in the future. We investigated the feasibility of high-resolution satellite imagery (0.5 m spatial resolution with red, green, blue and infrared bands) and deep learning methods in detecting tree mortality at the individual tree-level. We trained a deep learning model that was based on neural networks and U-Net architecture using 58 manually labeled images containing patches of tree mortality, mainly Norway spruce (*Picea abies* H. Karst) affected by the European spruce bark beetle (*Ips typographus* L.). The labeling was based on visual interpretation of the images by experts. The satellite imagery contained images from varying dates between June and November in the year 2022 from different regions of Southern Finland. Based on the accuracy metrics for the tree mortality detection, our methodology may increase the efficiency of tree mortality mapping for large areas and could provide a valuable tool for forest owners, managers and other stakeholders that are interested in the health of forests.

P3.19

Interannual dynamics of aboveground production classified by apical and cambium growths and its drivers in *Picea mariana*

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Abstract

Both stem cambial and apical growths have been used as indices when investigating the climate response of annual tree production. However, their interannual variations do not necessarily proceed synchronously. Thus, the drivers might differ between cambial and apical growths. Here we show the similarity of interannual variation between apical and cambial growths and examine if their driver is the same. Ten mature *Picea mariana* trees were harvested and their twenty branches per tree were collected from a fire regenerated open pure stand in the vicinity of Wood Buffalo National Park, NWT, Canada (ca. 60N-113W). Annual shoot length and tree-ring width on stems and branches were measured for about the past twenty years as annual apical and cambial growths, respectively. Drivers for each annual growth were analyzed using a linear mixed model, which was fitted with annual growth of a given year as the response variable; mean air temperature and total precipitation during growth and dormant seasons, and total length or diameter in the previous year as explanatory variables. Only two of the ten stems had a significantly similar interannual variation between apical and cambial growths. Stem apical growth was affected by air temperature during the previous growth season, but not by the total stem length, whereas its cambial growth was strongly controlled by the stem diameter and was not strongly affected by climate factors. It implies that stem cambial growth is not sensitive to climate change than stem apical growth. Branches had a weak similarity in the variation between apical and cambial growths, and both were affected by air temperature during the current growth season. Overall, the response to global warming might differ between apical and cambial growths, and between stem and branch growths. Measuring each of them separately would therefore improve the climate response analysis for annual tree production.

P3.20

The Effect of Different Mycorrhiza Species on Plant Transpiration Under Drought Conditions, and Morphology Changes in Pinus Sylvestris Seedlings

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Abstract

Drought affects plant water relations, by inducing stomatal closure to reduce water loss through transpiration, leading to reduced plant growth due to a decrease in photosynthetic activity. Ectomycorrhizal fungi (EMF) establish a symbiotic association with woody plant roots, increasing the root's absorption area in exchange for carbohydrates. Additionally, EMF increases the plant's resistance to environmental stresses, such as drought. Although the mechanisms to improve the plants' drought resistance are not yet clear, different hypotheses point to changes in root morphology, enzymatic activity, and nutrition. However, whether individual species of EMF have different effects on water-stressed plants remains understudied.

This study aims to analyze how different EMF species affect the growth of pine seedlings under water stress conditions and recovery period by analyzing the changes in transpiration and photosynthetic system. How these responses to drought are linked to differences in plant structure is further studied by analyzing possible changes in plant morphology and biomass production due to different EMF species. To test this, we inoculated potted one-year-old Scot pine (Pinus sylvestris) seedlings with one of ten common boreal forest EMF species. Half of the seedlings were kept under normal water conditions, and the other half was water-stressed for ten days and then re-watered for fourteen days to evaluate their recovery. During the experiment, the transpiration rate was measured by pot weight loss, and the needle water potential of the seedlings was determined using a pressure chamber. At the end of the experiment, we analyzed plant biomass, root morphology, needle color, photosynthetic fluorescence, and projected needle area.

The results show that some EMF species significantly increased the transpiration rate under water stress and during the recovery period. Additionally, we observed a slight effect of EMF on biomass, light response, and plant morphology. Overall, pine seedlings respond differently to different EMF species associations.

P3.21

Estimating intraseasonal intrinsic water-use efficiency from high-resolution tree-ring $\delta^{13}C$ data in boreal Scots pine forests

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Abstract

Intrinsic water-use efficiency (iWUE), a key index for carbon and water balance, has been widely estimated from tree-ring $\delta^{13}C$ at annual resolution, but rarely at high-resolution intraseasonal scale. We estimated high-resolution iWUE from laser-ablation $\delta^{13}C$ analysis of tree-rings ($iWUE_{iso}$) and compared it with iWUE derived from gas exchange ($iWUE_{gas}$) and eddy covariance ($iWUE_{EC}$) data for two *Pinus sylvestris* forests from 2002 to 2019. By carefully timing $iWUE_{iso}$ via modeled tree-ring growth, $iWUE_{iso}$ aligned well with $iWUE_{gas}$ and $iWUE_{EC}$ at intraseasonal scale. However, year-to-year patterns of $iWUE_{gas}$, $iWUE_{iso}$, and $iWUE_{EC}$ were different, possibly due to distinct environmental drivers on iWUE across leaf, tree, and ecosystem scales. We quantified the modification of iWUEiso by post-photosynthetic $\delta^{13}C$ enrichment from leaf sucrose to tree rings and by nonexplicit inclusion of mesophyll and photorespiration terms in photosynthetic discrimination model, which resulted in overestimation of $iWUE_{iso}$ by up to 11%and 14%, respectively. We thus extended the application of tree-ring $\delta^{13}C$ for iWUE estimates to high-resolution intraseasonal scale. The comparison of $iWUE_{gas}$, $iWUE_{iso}$, and $iWUE_{EC}$ provides important insights into physiological acclimation of trees across leaf, tree, and ecosystem scales under climate change or forest management and improves the upscaling of ecological models.

P3.22

Data rich forests - applying machine learning on forestal and environmental data

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Abstract

Forest and land management relies on data input. The availability of open accessible data sources from in-situ measurements until remote sensing products have increased the number of available datapoints per unit area drastically. Combining data from comprehensive long-term measurements offered by the Station for Measuring Ecosystem-Atmosphere Relations (SMEAR) Estonia, as example, with satellite remote sensed spatial data and forest inventories allows the creation of new data processing pipelines. One example in this context is the modelling of the forest ecosystems water balance including regionalisation of hydrological parameters which includes in-situ measured Eddy covariance, evapotranspiration, river discharge, and meteorology in concert with satellite products. Another example is the spatial explicit modelling of forest growth combining in-situ data with forest inventory informations to assess carbon fluxes within the SMEAR Estonia stations footprint.

Such data processing pipelines can be used as input to machine learning processes and enable higher spatially resolution with increased detail that help in decision making, resource planning and management activities.

P3.23

Comparative analysis of machine learning algorithms and statistical models for predicting crown width of *Larix olgensis*

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Abstract

Crown width is one of the most important crown dimensions that influence tree growth and survival. Accurate crown width prediction is vital for forest management. However, measuring crown width is time-consuming and labor-intensive, making it necessary to construct a convenient and accurate crown width prediction model. Nowadays, machine learning technologies have already been increasingly used to accurately predict tree growth, but there is still a lack of systematic and comprehensive comparison. This paper provided a comparative analysis of various machine learning methods (i.e., the Linear Regression, the Least Absolute Shrinkage and Selection Operator, the k-NearestNeighbors, the Random Forest, the Gradient Boosting Decision Tree, the Support Vector Regression, the Voting Regressor and the Multi-Layer Perceptron), simple crown width-diameter of breast height model, generalized crown width-diameter of breast height model and nonlinear mixed-effect crown width model for estimating the crown width of Larix olgensis in terms of the coefficient of determination, root mean squared error, mean absolute error, and mean absolute percentage error using hold-out validation and 10-fold cross-validation. The study showed that machine learning algorithms performed better than common nonlinear regression and nonlinear mixed-effect models. Specifically, the voting regressor and random forest algorithm yielded the highest prediction quality of crown width among the different models. In addition, from a practical point of view, the advantage of machine learning is that its implementation does not require crown width measurements. On the contrary, the calibration of the mixed-effect model requires prior information, which limits its use.

P3.24

Retrieving boreal forest structure from remote sensing data with a reflectance model and machine learning methods

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Abstract

In forests, the variables describing the canopy structure are directly coupled with radiative transfer in vegetative canopies. Physically-based radiative transfer models, also known as forest reflectance models, can describe the transfer of solar radiation within the vertical forest canopies and interpret the interactions of solar radiation with forests.

Well-calibrated forest reflectance models can be used to simulate the reflectance of different forests when given the correct input parameter values. Several methods can be used for their inversion, i.e., estimation of forest variables from forest reflectance spectra. Machine learning algorithms are increasingly being used as inversion tools but require a representative database of forest properties and reflectance spectra, which is difficult to obtain from measurements. Instead, reflectance models can be used to simulate a myriad of different forest spectra yielding a database that would cover the entire natural range of existing forest structures.

We explore the use of machine learning tools to construct a hybrid inversion method for a well-validated geometric-optical forest reflectance model, namely the Forest Reflectance and Transmittance model FRT. We use the novel hybrid method to retrieve forest variable estimations from boreal forests of Finland and Sweden. The performance of the model is evaluated using different training and test sets. The aim is to understand the optimal training data needed for accurate forest variable estimations. We use an extensive set of field plot data covering the whole Finland to test the influence of forest variable distribution on the retrieval accuracy. Additionally we try to assess the possible added benefit of additional data that may be available for the imaged area. Furthermore, we assess the advantages of hyperspectral over multispectral remote sensing data. Lastly, we evaluate the geographical transferability of the hybrid method using national forest inventory plots from the hemiboreal southern Sweden.

P3.25

Operational system for tree-wise actual carbon verification based on mobile laser scanning, artificial intelligence and blockchain

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Abstract

There is a lack of consistent methodologies and standards for quantifying and verifying carbon captured by trees, leading to difficulties in comparing and valuing credits across different projects. There are concerns about the transparency and accountability of some carbon offset projects, as well as the possibility of "double counting" of emissions reductions. Many consumers and businesses are unsure about the credibility of offset projects. Measuring the actual emissions reductions from carbon offset projects can be challenging and may require independent verification.

The prototype of operational system for tree-wise actual carbon verification based on mobile laser scanning, artificial intelligence and blockchain was developed in Natural Resources Institute Finland and function as follows:

Mobile laser scanning technology is used to collect detailed information on each individual tree, including its size, shape and volume.

Artificial intelligence algorithms are used to process this information, identify tree species, quantify the tree structure and estimate the amount of carbon stored in wood of each tree by comparing scans over at least two periods of time.

The carbon storage estimates for each tree are recorded on a blockchain platform, creating a transparent, secure and tamper-proof record of the carbon captured by each tree.

Stakeholders such as government agencies, environmental organizations and carbon market participants can access this information through the blockchain platform to verify the carbon captured by each tree.

The information can be updated on demand to keep track of changes in carbon capture over time, providing a dynamic and accurate picture of carbon storage in the forest.

This system provides a tree-wise, verifiable and secure record of carbon capture to enable effective carbon credit trading and monitoring.

P3.26

The effect of restriction of plant-derived C flow to fungal communities in soil organic matter in a Scots pine forest

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Abstract

The soil organic matter (SOM) of boreal forests stores significant amounts of carbon, and fungi, including saprophytic and ectomycorrhizal fungi, play an important role in degrading this carbon. Ectomycorrhizal fungi can antagonize saprophytic fungi and slow down the decomposition of SOM, in a process called "Gadgil" effect. Additionally, rhizosphere exudates and dead roots stimulate saprotrophs, thereby accelerating the decomposition of SOM in another process known as the rhizosphere priming effect. So how do fungal communities, especially saprophytic and ectomycorrhizal fungi, interact in SOM of boreal forests? For this, we established a 4-year field experiment with three different trenching treatments: 1) to exclude roots and mycorrhizal hyphae (mesh with 1-µm pores); 2) to exclude roots, but not mycorrhizal hyphae (mesh with 50-µm pores) and 3) a control treatment that included roots and mycorrhizal hyphae. Additionally, we removed all ground vegetation, left only ericoid dwarf shrubs or left the ground vegetation intact. To samples taken from all these 9 treatments, we applied DNA-based MiSeq sequencing and multivariate statistical analyses to explore fungal communities. According to the "Gadgil" effect, we hypothesize that 1) in the 1-µm pores trenching treatment, the abundance of saprophytic fungi will increase with time due to the absence of roots and ectomycorrhizal fungi; 2) in the 50-µm pores trenching treatment and control, where the saprophytic and ectomycorrhizal fungi coexist, thereby ectomycorrhizal fungi will inhibit saprophytic fungi and reduce the abundance of saprophytic fungi with the time. The preliminary results will be presented in the poster.

P3.27

Regeneration of Scots pine (*Pinus Sylvestris*) in proximity of mature trees in nutrient poor soils

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Abstract

Even-aged forestry is the most common forestry practice in boreal forests. Harvesting of all trees within a given area, i.e., clear-cutting, liberate regenerating seedlings from competition with mature trees. However, clear-cutting has been under intense debates and public demands now favor a transition to clear-cut-free forestry, i.e., continuous cover forestry (CCF). In the choice of harvesting method, it is important to recognize how different tree species regenerate in the proximity of mature trees. In Scandinavia, Scots pine (Pinus sylvestris L.) is commonly used in forestry. We aim to study the regeneration of Scots Pine in proximity of mature trees in nutrient poor soils of northern Sweden. The study tests the regeneration success of sown and planted Scots pine seedlings in three environments (under forest canopy, at the forest edge and out on a clear-cut) and three treatments (root isolation by steel frames, nitrogen fertilization and control). Root isolation enhanced seedling performance under the canopy of mature trees despite the lower light conditions. Nitrogen fertilization alleviated seedling performance in full light conditions, to a greater extent out in the clear-cut than in the forest edge, but competition for light appeared to prevent efficient utilization of N-fertilization in the forest. Our results agree with studies that rank underground competition as the most limiting resource on poor soils and light as the most limiting resource on fertile sites, and highlights why small canopy openings are not optimal for Scots pine regeneration.

P3.28

Introduction to IUFRO: International Union of Forest Research Organizations

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Abstract

IUFRO, the International Union of Forest Research Organizations (https://www.iufro.org/), offers a global network for voluntary cooperation. The network is open to all individuals and organizations dedicated to forest and forest products research and related disciplines. IUFRO aims to contribute to achieving the Sustainable Development Goals set by the United Nations.

IUFRO is a global, non-profit, non-governmental and non-discriminatory organization established in 1892 with headquarters in Vienna, Austria. It unites about 650 member organizations in more than 120 countries representing over 15,000 scientists. 70 meetings are held on average every year. One can join any of the 9 scientific Divisions, over 50 Research Groups, more than 180 Working Parties and 8 interdisciplinary Task Forces. There are almost 700 voluntary coordinators of these units. IUFRO coordinates a number of including Special Programmes and projects: Special Programme for Development of Capacities (IUFRO-SPDC); Special Programme Directors' Forum (IUFRO-SPDF); Project on World Forests, Society and Environment (IUFRO-WFSE); Global Forest Expert Panels (GFEP) Programme.

IUFRO World Congress is one of the largest global forest events, held every five years since 1893. The XXVI IUFRO World Congress (https://iufro2024.com/) will take place in Stockholm June 23–29, 2024. The congress gives a unique opportunity to gather worldwide leading scientists and top leaders to contribute and co-create for a sustainable future within Forestry, Climate and Society – aligned with the UN´s 2030 Agenda for Sustainable Development and the future ahead.

IUFRO is a co-sponsor of many IBFRA activities.

P3.29

Provenance-specific dynamic height growth model for lodgepole pine in Eastern Baltic region

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Abstract

Lodgepole pine (*Pinus contorta* Dougl. var. *latifolia*) is a native species of North America, which has been successfully introduced in the Baltic sea region and elsewhere in Europe, with the largest economic importance in Sweden due to fast initial growth, resistance to harsh environmental conditions, and potentially higher productivity compared to Scots pine. In Latvia, experimental trials of lodgepole pine have been established since the early 1980s, and the available data from remeasured trees after four decades now allow to develop growth models up to at least mid-rotation, hence assessing the performance of the tested provenances. In context of climate change adaptation, farsighted decisions regarding assisted migration at both inter- and intra- species level can be informed by analyzing and choosing well-performing origins of native and introduced species.

We used the generalized algebraic difference approach (GADA) to model individual tree height growth of lodgepole pine provenances. The modelling was based on data from provenance trials in Latvia with an age range of up to 40 years, comprising study material of 33 origins from North America. We used mixed-effect modelling approach, applying the provenance as a random effect on the parameters of commonly used dynamic height growth derivatives.

Dynamic form of Hossfeld equation derived by Cieszewski had the best fit. The model coefficient β_1 showed a significant variation between provenances, reflected by distinct differences in provenance-specific growth trajectories, especially asymptote. The differences were consistent over presented site quality range. The best performance was shown by the origins of Babine Lake and Summit Lake, while provenances from Alberta and Bonaparte Lake had the slowest height growth.

The developed model with provenance-specific coefficient β_1 reasonably reflected the actual growth of the studied provenances and could be used to support decisions regarding selection of well-adapted provenances for climate-smart utilization in the Eastern Baltic region.

P3.30

Competition effect on periodic annual increment in middle-aged Betula pendula plantations

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Abstract

Silver birch plantations on former agricultural lands are showing higher growth and yield than the native birch stands on forests land in Northern Europe. Hence, there is a need to clarify whether silvicultural recommendations for forest stands are applicable for plantations where different stand structure and high soil fertility may alter competition between trees. This study was initiated to find out which competition index (CI) and competitor selection method are most suitable to predict competition effect on periodic annual increment during 16–21 years of age in silver birch plantations. Further, it was clarified whether adding a weight to competitor trees based on their cardinal direction from the target tree would improve the growth prediction of CIs. All trees locations in 0.1 ha sample plots in 11 silver birch plantations were mapped and trees growth parameters were measured. Birch forests on forest land in a similar site type showed about 2-fold lower mean annual increment (5.6 m^3 ha^{-1} yr^{-1}) compared to the same age silver birch plantations on former agricultural lands (14.1 m^3 ha^{-1} yr^{-1}) during the study period. According to Akaike information criterion, the best CI for predicting the basal area increment for all tree sizes was CI with the reverse cone approach for competitor selection. Adding a weight to competitor trees based on their cardinal direction from the target tree, improved the performance of CIs for dominant trees but not for suppressed trees. The comparison of performance of CIs expressing asymmetric and symmetric competition suggested that at the given fertile sites and plantation age, asymmetric competition was the prevailing mode of competition affecting growth of silver birches. High level of light competition and subsequent self-thinning in unmanaged plantations suggest that silver birch plantations need to be managed more intensively than forest land birch stands.

P3.31

The present and future state of forest use and management in the Puruvesi catchment area – perceptions from Finnish stakeholders

Liina Häyrinen, Katriina Soini

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Abstract

Given the pressures towards forests' carbon sequestration, preventing biodiversity loss and protection of ecosystems (e.g., vulnerable water systems), decisions on forests' use and management are increasingly important. Local forest stakeholders play a key role in implementing and contributing to sustainable forestry management practices. Understanding their perceptions offers insight into how sustainable forest use and management can be promoted simultaneously considering also local conditions.

The aim of this study is to investigate the perceptions of the various forest stakeholders (i.e. forest landowners, forestry advisors, forestry and environmental authorities, timber buying companies, forestry entrepreneurs, and NGOs) in the Puruvesi catchment area regarding the current status as well as the probable and preferable futures of forest use and management. The research data were collected through 22 forest stakeholder online interviews and were analyzed qualitatively with content analysis.

The results showed that the current forest use and management in the area was characterized by active forestry operations. At the same time, the effects of the intensive forest use and management on the lake Puruvesi were emphasized in the interviews. Regarding the possible changes in the operating environment of forest use and management by 2023, stakeholders discussed that issues related to promoting biodiversity, forest carbon sequestration and multiple use of forests will be emphasized more in the future. However, also changes related to forest ownership and possible restrictions on forest use from EU were brought up in the interviews. For the forest use and management by 2035, interviewees called for more consideration and variation in forest management practices, although the continuation of wood production alongside an increasing emphasis on other ecosystem services was considered as crucial for the area.

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