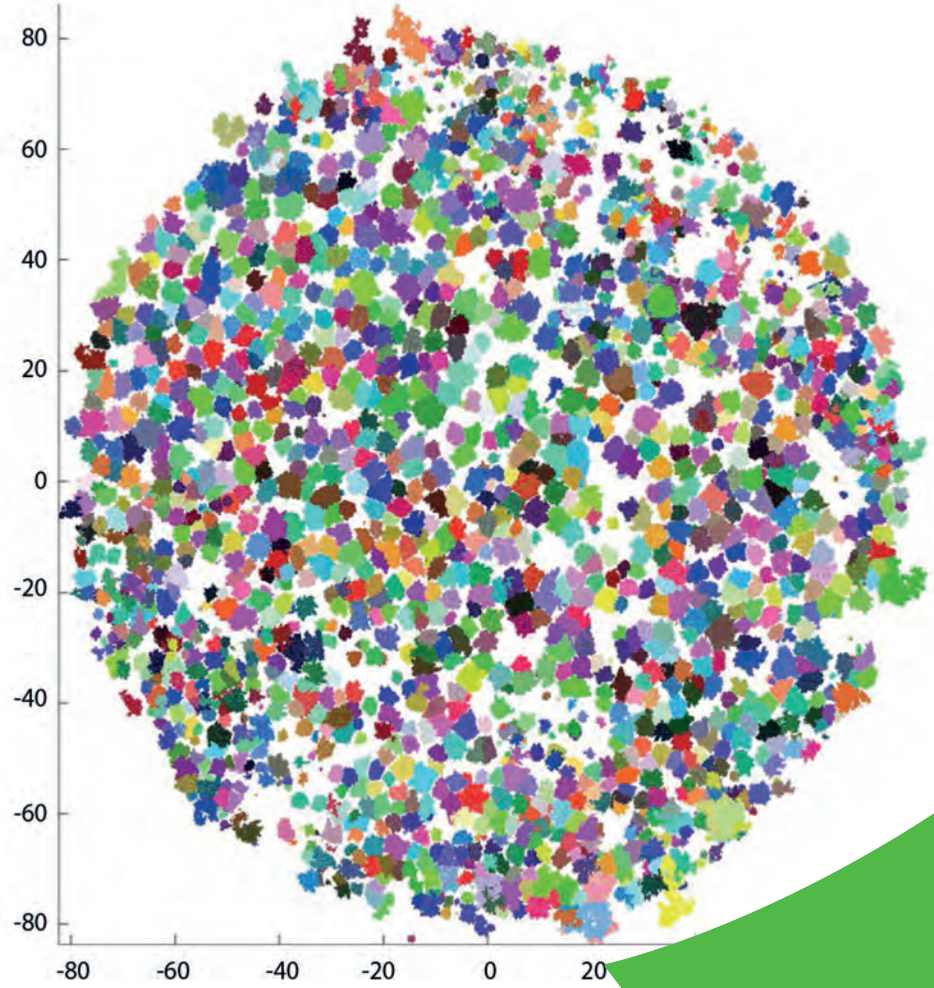

Natural resources and
bioeconomy
studies 29/2015

Towards a New Era of Forest Science in the Boreal Region

Abstracts of The 17th IBFRA Conference May 24–29, 2015, Rovaniemi, Finland

Raisa Mäkipää and Tuire Kilponen (eds.)

Luke
NATURAL RESOURCES
INSTITUTE FINLAND

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Welcome to the IBFRA Conference ‘Towards a New Era of Forest Science in the Boreal Region’

Dear Conference Delegates,

On behalf of the International Boreal Forest Research Association (IBFRA), I am pleased to welcome you to the 17th IBFRA Conference ‘Towards a New Era of Forest Science in the Boreal Region’. I would like to thank you for joining the conference and hope that you will enjoy an inspiring scientific program together with colleagues from all regions of the boreal forest.

The International Boreal Forest Research Association was founded in 1991 to foster pan-boreal research and facilitate communication of research results relating to this immense forest biome. The boreal forest is vast and important for many key ecosystem services. Simultaneously, the boreal forest has large regional differences in both management practices and ecological processes. I believe that through increased collaboration within the boreal, we can further our understanding of the key ecological processes and how they impact ecosystem services, and in turn inform both forest management and forest policy. I hope that this conference and other IBFRA activities can help facilitate such increased boreal collaboration.

We are in a time of change on many fronts – climate change will have large impacts on the boreal forest and the required shift to the bioeconomy will reinforce the need for sustainable forest management. At the same time, technology can and will change the ways we collect information, monitor changes or management, and conduct research. Hence, I believe that this conference “Towards a New Era of Forest Science in the Boreal Region” with themes ranging from bioeconomy and sustainable forest management in an era of global change to big data is both timely and important.

On behalf of IBFRA, I would like to thank the local conference organizers from the Natural Resources Institute Finland (Luke) and the co-organizers from the University of Lapland and the Arctic Center.

I hope that you will enjoy the conference and continue your involvement with IBFRA in the future!

Rasmus Astrup

IBFRA President

Welcome to the IBFRA Conference 'Towards a New Era of Forest Science in the Boreal Region'

Dear Friends and Colleagues,

Advances in forest science can provide solutions for sustainable use of forest resources, and information flow between research groups can generate new solutions and innovative ways to solve timely research questions. For instance, predictive models that are applied for regional planning in a changing environment or for evaluation of the management alternatives are developing fast and international co-operation will enhance their applicability to new conditions as well as their reliability. Big data collected with new instruments will open a new avenue for fast development of methods and services that can be used in the forest sector. As the use of big data provides new possibilities for the forest sector, it is important that scientists discuss strengths and challenges of the new data processing approaches and technologies. This conference provides a forum for intensive discussions on new findings of forest research, on challenges and advances in data analyses, as well as on effects of global change on the status and future of the ecosystem.

On behalf of the Natural Resources Institute Finland, I am pleased to welcome you to the 17th IBFRA Conference 'Towards a New Era of Forest Science in the Boreal Region'. The conference is organized by the Natural Resources Institute Finland (Luke), which is a new research institute established 1.1.2015. However, you may remember us from the past since the Finnish Forest Research Institute (Metla) was merged into this new research institute at the beginning of 2015. Co-organizers of the conference are the University of Lapland and Arctic Center.

We cordially thank our sponsors and partners who made it possible to organize the IBFRA 2015 conference. We also thank the members of the International Program Committee for the support in building the scientific program of the conference. Our fundamental thanks go to all attendees who wanted to share their knowledge, scientific findings, and innovative solutions with us during the conference days. Enjoy your conference!

Raisa Mäkipää

Conference Chair
Senior Research Scientist, Natural Resources Institute Finland

Committees

The International Program Committee

Raisa Mäkipää, Natural Resources Institute Finland, chair

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Pierre Bernier, Natural Resources Canada
Susan G. Conard, George Mason University, USA
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Marja-Leena Porsanger, Rovaniemi-Lapland Congresses
Eija Virtanen, Natural Resources Institute Finland
Mirja Vuopio, Natural Resources Institute Finland

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POHJOLAN
Osuuspankki

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09:20 -10:10 **Keynote 4.** Kaasalainen, Mikko: **Big forest data and inverse problems: new-generation 3D/4D forest models**, Chair: Astrup, Rasmus

10:10 - 10:30 *Coffee*

10:30 -12:30

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12:30 - 13:30 *Lunch*

13:30 - 15:00 **Poster Session**

15:00 - 15:20 *Coffee*

15:20 - 16:40

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THURSDAY 28 MAY, Arktikum

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A5.2 Sjølie, Hanne K. — Regional and agent group welfare impacts of forest climate policies

10:00 - 10:30 *Coffee*

10:30 - 12:30

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B6: Sighting the future of forests,
Chair: Kraxner, Florian

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12:30 - 13:50 *Lunch*

13:50 - 14:20
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13:50 - 15:10
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B7.4	Discussion on publication plans of the Big-data presentations – shall we plan for book chapters or journal articles?	

15:10 - 15:40 *Coffee*

15:40 - 17:00
A8: Ecosystem services, Chair: Nordin, Annika

A8.1	Parviainen, Miia	Quantification and valuation of ecosystem services to optimize sustainable re-use for low-productive drained peatlands
A8.2	Kraxner, Florian	Forest management certification - application of a new tool for certification mapping to the boreal forest

B8: Forest disturbances by biological agents, Chair: Snäll, Tord

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B8.2	Björkman, Chister	Insect pests in future forests: Utilizing complex interactions to mitigate damage

A8.3	Kaukonen, Maarit	Securing forest ecosystem services in Finnish state-owned multiple-use forests managed by Metsähallitus	**B8.3**	Soukhovolsky, Vladislav	Modeling and prediction of forest insect population dynamics
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17:10 - 17:45 **Posters** - Awards and presentations of the best IBFRA posters

19:00 - 23:00 **Conference Dinner**

FRIDAY 29 MAY, Arktikum

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09:20 - 10:10 **Keynote 7.** Bergsten, Urban: **From tree assortments to an engineering biomaterial in industry**, Chair: Hånell, Björn

10:10 - 10:30 *Coffee*

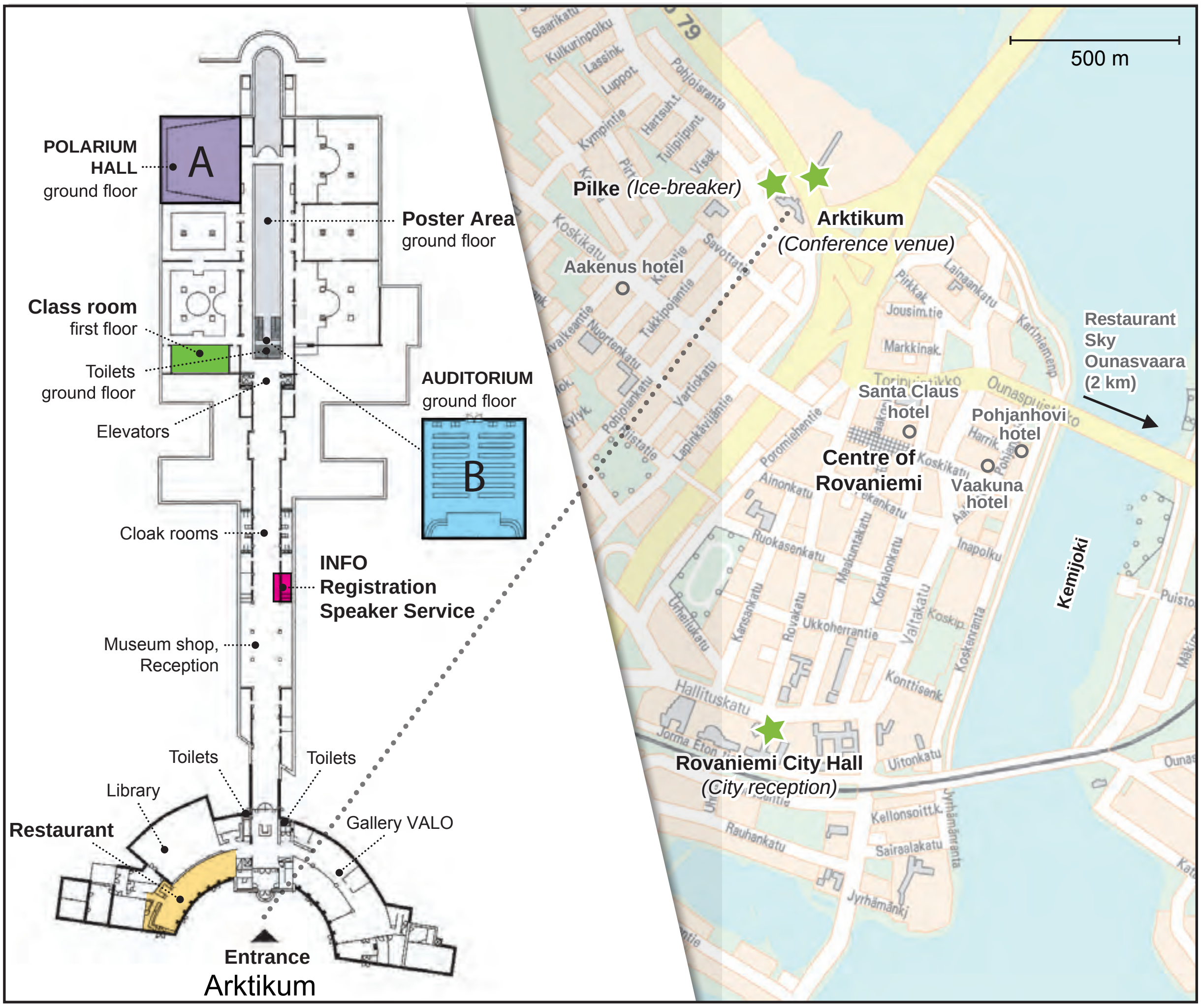
10:30 - 12:00 **Panel discussion**: What are the major forest related questions in where contribution of the scientists is needed?

Panelists:
Kalle Einola, Manager (Technology, Product Safety & IPR), PONSSE
Tuomo Kauranne, President, Arbonaut Ltd, and Scientist, Lappeenranta University of Technology
Anneli Nordin, Programme Director, SLU Future Forests
Werner Kurz, Leader of the National Forest Carbon Accounting System for Canada, Natural Resources Canada

12:00 - 12:30 **Summary and Closing Ceremony**

12:30 - 13:50 *Lunch (OR Bus to the airport, snack and departure AY428 at 13:50)*

Conference venue



KEYNOTE ABSTRACTS

Keynote 1

Climate change mitigation potential of the boreal forest sector

Werner Kurz [1], Carolyn Smyth [1], Tony Lemprière [2], Greg Rampley [2]

[1]Natural Resources Canada, Canadian Forest Service, Victoria, Canada
[2]Natural Resources Canada, Canadian Forest Service, Ottawa, Canada

Forests play an important role in the global carbon cycle and changes in land management, and in particular reducing global rates of deforestation and degradation, can make an important but limited contribution to efforts to reduce greenhouse gas concentrations. Boreal forests are characterised by slow growth rates, a high proportion of carbon in dead organic matter and soils, low human population densities, limited competition for food production, and low deforestation rates. Biomass carbon stocks in boreal forests are estimated to be increasing, albeit with regional differences, and with unknown time to saturation and high vulnerability of carbon stocks to the impacts of climate change.

Assessing climate change mitigation options in the boreal forest sector requires an integrated systems approach including the quantification of changes in emissions in forests ecosystems, harvested wood products (HWP) (including landfills) and the avoidance of emissions through the use of HWP and wood-derived bioenergy. Mitigation analyses should also consider biophysical factors such albedo. Mitigation options through reduced deforestation or increased afforestation are limited in most boreal forests because baseline deforestation rates are low and existing forest cover is high. About 42% of the global increase in HWP carbon stocks over the period 1990 – 2008 originated from boreal forests. Enhancement of sustainable forest management and thus the increases in carbon uptake rates combined with increases in the amount of C stored in long-lived (engineered) HWP and the resulting emission reductions in other sectors offer the greatest opportunities for climate change mitigation in the boreal forest sector.

Keynote 2

Sustainable management of boreal peatlands for mitigation of climate change

Andrey Sirin

Institute of Forest Science, Russian Academy of Sciences, Moscow Region, Russia

Peatlands are essential ecosystems of the boreal zone as excessive moisture promotes paludification. In many countries, peatlands (forested, sparsely treed and open) belong to forest lands. Forest vegetation indicates better drainage and, hence, peatlands are more dependent on climate. The water balance is key to the stability of peatlands; shallow peatlands are the most vulnerable to climate change. Peatlands contain disproportionally more organic carbon than neighboring ecosystems on mineral soils including forests. They also affect atmospheric burdens of CH_4 and N_2O, which are much stronger greenhouse gases than CO_2, thus playing a complex role with respect to climate. GHG fluxes in peatlands vary both spatially (ecosystem, site, etc.) and temporally (interannual, seasonal, diurnal, etc.), and this needs to be considered in assessment and management. Small changes in the hydrology and ecology can lead to big changes in GHG fluxes. Direct (forestry, agriculture, peat extraction) and indirect (construction, etc.) peatland uses are usually linked to drainage which leads to increased CO_2 emissions in general, an increase in N_2O release from nutrient-rich peatlands, and may not always significantly reduce CH_4 emissions. Nowadays, large areas of boreal peatlands drained for agriculture have been abandoned, many drained forests have already reached the end of their rotation thus raising the question of their post-harvest use, and peat extraction is decreasing. Restoration of degraded peatlands is one of the most cost-effective ways of avoiding anthropogenic GHG emissions. However, in order to be climatically beneficial, a wise use approach integrating protection, sustainable use and restoration of peatlands is needed.

Keynote 3

Mass data processing and data integration for large area characterizing forest cover, change, and structure

Mike Wulder [1], Joanne White [1], Geordie Hobart [1], Nicholas Coops [2], Txomin Hermosilla [2]

[1] Canadian Forest Service, Victoria, BC, Canada
[2] University of British Columbia, Vancouver, BC, Canada

Long-term monitoring of boreal forest ecosystems is required to implement sustainable forest management in an era of global change. Free and open access to analysis-ready satellite image products (e.g., Landsat) provides a valuable data underpinning to reduce monetary and processing costs. Calibration and validation data from traditional sources such as field plots can also be supplemented by unique, but analogous measures, from airborne laser altimetry. The end goal of producing data products that support science, monitoring, and reporting activities is promoted, facilitating the flow of information from scientist to policy makers and the wider public. To support these aims, we have been using tens of thousands of Landsat images to characterize on an annual basis conditions and changes over Canada's forests in a systematic and transparent fashion for the period from 1984 to present day. We are now poised to address many questions related to forest change, including both depletions (largely via fire and harvest) as well as recovery post disturbance. Information products developed from Landsat imagery are informative and relevant at a range of spatial scales, but with their 30 m spatial resolution, these products are capable of capturing anthropogenic impacts, which makes them particularly informative at management scales. The aim of this presentation is to set the context and describe the products being generated, offer insights on analysis decisions made, and to communicate key findings.

Keynote 4

Big forest data and inverse problems: new-generation 3D/4D forest models

Mikko Kaasalainen[1], Pasi Raumonen[1], Ilya Potapov[1], Sanna Kaasalainen[2], Raisa Mäkipää[3], Risto Sievänen[3], Jari Liski[4]

[1]TUT, Tampere, Finland
[2]FGI, Masala, Finland
[3]Natural Resources Institute Finland (Luke), Vantaa, Finland
[4]SYKE, Helsinki, Finland

Modern growing demands on forest information for multiple ecosystem services cannot be met by the simple and limited trunk volume and canopy size estimates currently in use. Laser scanning techniques have brought about the possibility to map trees and forests efficiently in 3D detail. These quantitative structure models (QSMs) contain any desired geometric, volumetric, and topological properties of the trees. With the advent of lightweight and mobile scanners (ubiquitous laser scanning), this will, for the first time, allow the fast and precise 3D mapping of entire forests from billions of data points. We expand this scheme to 4D (growth predictions) by modifying theoretical plant growth algorithms to have stochastic components that produce the characteristic structural properties for each species.

The measurements are made by a large domestic and international collaboration network that also develops new types of instruments, such as the hyperspectral lidar that allows the identification of the surface material (chlorophyll, moisture, the condition of the tree, etc.) in addition to the laser scanning point cloud. This approach allows the mapping of forests with unprecedented detail and quality. We have shown by field experiments that, with our modelling, the volumetric accuracy of tree biomass estimates is 10% or better, while other contemporary methods can reach an accuracy of no better than roughly 50% and lack the topological and geometric off-trunk information.

Keynote 5

Species reports by the public as a basis for species projection in forest scenario analysis

Tord Snäll

Swedish University of Agricultural Sciences, Uppsala, Sweden

Currently, the Swedish Forest Agency is conducting yet another Forest Scenario Analysis (FSA). FSA aims to describe the consequences of scenarios of future forestry policy. Effects on, e.g., wood production have long been studied. However, national FSA should also compare viabilities of species among the scenarios. An appropriate approach to compare species viability among scenarios is population viability analysis. Such an analysis includes a model for population dynamics of the focal species. However, developing a population model is usually a long or costly process. I will show how applying simple population models based on readily available data may affect conclusions about future species viabilities among forestry scenarios. Two types of population models will be applied, [1] models based on data collected using a systematic sampling design, and [2] models based on species observation data reported by the public to open-access websites, so called Citizen Science Data (CSD). The key question that will be answered is whether projections of future species viabilities differ among forestry scenarios depending on the type of model applied – do the two model types ([1] or [2]) give different messages about future species viability? I will use the scenarios formulated for the ongoing FSA: business-as-usual, increased conservation, increased wood productivity, much increased temperature (RCP 8.5), and combinations of these.

Keynote 6

Bioeconomy – research knowledge facilitates switch from fossils to bio-based economy

Leena Paavilainen

Natural Resources Institute Finland (Luke), Finland

Competition for resources – natural resources, water and energy – will increase globally due to the economic growth and growing population. This development promotes the transition from fossil economy to bioeconomy, being the new wave of economic development. Bioeconomy includes the use of renewable bio-based natural resources, environmentally friendly clean technologies, efficient recycling of materials and new operating models.

We in Finland have built a strong knowledge and competence base in sustainable and resource-efficient utilization of renewable raw materials, especially forest resources, for optimal and innovative end-uses. Our forests are vital and productive. Over 70% of our bioeconomy output and added value and over 90% of the exports today come from the forest-based bio-economy. Finland and all of Europe are looking for economic growth and new jobs from bioeconomy. The bioeconomy growth is boosted by the OECD bio-economy agenda and the EU's bio-economy strategy. The Action Plan covers policy actions and stakeholder engagement, enhancement of markets, and investment in knowledge, innovation and skills. The objective of the Finnish Bioeconomy Strategy, adopted last year, is to increase the bio-economy output from 60 to 100 billion and to create 100 000 new jobs. Its realization calls for systematic change, crossing of sectorial boundaries in research, demonstration platforms for commercialization of innovations and securing the availability of raw materials.

To aggregate the development of a bio-based society, the Finnish Forest Research Institute (Metla), MTT Agrifood Research Finland, the Finnish Game and Fisheries Research Institute (RKTL) and the Information Centre of the Ministry of Agriculture and Forestry (Tike) joined forces in 2015 to form the Natural Resources Institute Finland (Luke). Luke promotes the development of innovative solutions along the entire value chain from customer to renewable raw material resources. It is a strong center of excellence with multidisciplinary competences – strong expertise on policy support, multiple skills in ecology, economics and social sciences. It also has unique research infrastructure with long-term series of research materials, data resources, and functional field trial and laboratory services. The customer is at the focus of Luke's activities. The strategic impact areas – biomass-based products and energy, food system and food security, health and well-being, economy and policy actions on natural resources – are based on renewable natural resources. Examples are given how Luke through its RTI programs boost bioeconomy in wood construction, high value added products and chemicals, bioenergy and biofuels, and health and well-being.

Keynote 7

From tree assortments to an engineering biomaterial in industry

Urban Bergsten

SLU, Dept. of Forest Biomaterials and Technology, Umeå, Sweden

Large-scale commercial production of new biorefinery products could be possible in the near future thanks to the wide range of biomaterials that can be produced from tree biomass. It may though be necessary to better define tree assortments based on their properties as an engineering material in industry. The chemical properties (e.g., content of extractives) may, for example, receive increased attention soon. Therefore, guidelines for silviculture should not only include estimates of biomass development but also quantify the amount of extractives per hectare that could be obtained over time in different tree parts. The silvicultural regime affects yield of extractives, depending on, e.g., the actual composition of species, site fertility, tree age, tree partitioning and tree size. Improved estimation of assortments' material properties may facilitate a cost-effective transition to a bio-economy.

ORAL PRESENTATIONS

A1.1

Towards holistic climate assessment of boreal forest management

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In addition to enhancing carbon sinks, managing forests for climate change mitigation requires a parallel understanding of the intrinsic biogeophysical mechanisms by which forests regulate climate. These include, among others, surface albedo, aerodynamic roughness, and canopy conductance. These mechanisms shape forests' ability to absorb and emit radiation, dissipate and accumulate turbulent heat, and store and transpire moisture. These climate regulation services and the intrinsic biogeophysical mechanisms shaping them are controlled by forest structural and physiological attributes as well as the physical environment, making them highly specific in (and variable across) time and space. While the importance of including biogeophysical considerations in climate assessments is growing in acceptance, resource managers are continually challenged by the lack of meaningful metrics and indicators available to carry out meaningful assessments, which, ultimately, impedes their ability to make informed decisions surrounding climate-effective forest management strategy.

Using a case region in boreal Norway, we develop high-resolution spatially explicit metrics that inform resource managers about the contribution of forests' intrinsic biogeophysical mechanisms in the regulation of local climate (air temperature and water vapor) relative to that which is advected due to large-scale atmospheric circulation. Together with maps of forests' carbon cycle value to the global climate system, such metrics can provide a means for resource managers to begin identifying important climate tradeoffs and win-win management strategies.

A1.2

Full climate impact of managed boreal forests

Tuomo Kalliokoski[1, 2], Mikko Peltoniemi[3], Stefan Fronzek[4], Brent Matthies[1], Lauri Valsta[1], Ditte Mogensen[5], Anni Vanhatalo[1], Jaana Bäck[1], Luxi Zhou[5], Michael Boy[5], Kari Minkkinen[1], Nea Kuusinen[1], Frank Berninger[1], Annikki Mäkelä[1], Eero Nikinmaa[1]

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Boreal forests have an important role in the mitigation of adverse effects of climate change. Here, we estimated the full impact of boreal forest management on radiative forcing, simultaneously considering the effects of carbon, albedo, aerosol, as well as direct and indirect effects of industrial wood use. We made analyses in both the current climate and that of year 2050, as projected by the median climate model in SRES A2 emission scenario.

The climatic effects of albedo and aerosol of coniferous forests were of similar magnitude but opposite and thus cancelled each other out under the current climate. In the projected climate of 2050, the radiative cooling of aerosols increased to the level equaling forest carbon fixation. Although the carbon stocks of broadleaved trees were smaller than those of conifers, their total radiative cooling effect was larger due to the albedo and aerosol effects. Doubling the current level of yearly cutting volume had a clear, direct warming effect on radiative forcing of forests, while cuttings corresponding to the annual wood growth had a neutral effect and cuttings less than that had a clear cooling effect. If substitution of non-wood products by wood products was included in the analyses, then all cutting schemes had the radiative cooling effect.

In light of the full climatic impact of boreal forests, broadleaved trees should be favoured over conifers if the goal is to mitigate climate change. Intensive cuttings and storing the carbon in long lasting end products is another efficient mitigation option. These strategies also apply in the future climate.

A1.3

Negative emissions from boreal forests – BECCS potentials and economic implications

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Scientists and policy-makers lead an active debate on the possibility of using bioenergy in combination with carbon capture and storage (BECCS) to remove CO_2 from the atmosphere. The overall objective of this study is to analyze the theoretical in-situ BECCS potential of boreal forests with special emphasis on Russia. This paper also aims at identifying wider implications of BECCS introduction. We first examine the technical potential of bioenergy production in Russia from domestic forest biomass by applying the global forestry model (G4M). In the second step, these results are used as input data to an engineering model (BeWhere) for optimizing scale and location of combined heat and power plants (CHP). Through overlaying with a geological suitability map, a theoretical potential for ”in-situ” BECCS is derived.

Preliminary results indicate that by using less than 10% of the annual wood removals in Russia, the supply of 50 green-field biomass plants could be supplied and the energy generated from forest-based bioenergy could be tripled. The theoretical BECCS potential of negative emissions under this high-capacity scenario could be 2 – 4 $MtCO_2$/yr. Moreover, co-benefits such as the substitution of bioenergy for fossil fuel-based energy, also leading to improved air quality with potentially large health benefits, need to be considered. Comprehensive planning of new bioenergy facilities and the corresponding feedstock production will not only lead to added economic value in terms of additional employment and a boost to rural development, but also open up opportunities for conserving the vast biodiversity in boreal forests.

A1.4

Potentials of forest biomass production and utilization in climate change mitigation in managed boreal forests

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Production and utilization of forest biomass provide a large potential for climate change mitigation in boreal forests. Using proper forest management, it is possible to either increase carbon density in forests or indirectly reduce CO_2 emissions by increasing the use of forest-based products to substitute for fossil-intensive materials and fossil fuels. In this work, the net climate impacts (in terms of radiative forcing) of forest-based materials and energy in substituting fossil-based materials and energy were calculated in the managed Finnish boreal forests. We employed forest ecosystem model simulations for assessing carbon sequestration and biomass production of forests and a life cycle assessment (LCA) tool for assessing net climate impacts of biomass utilization. The effects of alternative forest management scenarios on net climate impacts were calculated by integrating the carbon sink/source dynamics in both biosystem and technosystem. The current forest management was used as a reference management. Our results showed that the use of forest-based materials and energy in substituting fossil-based materials and energy would provide an effective option for mitigating climate change. In addition, forest management could be utilized to enhance the climate change mitigation potential of forests. However, the climate impacts varied substantially over time depending on the prevailing forest structure and biomass assortment (timber, energy biomass) used in substitution.

A1.5

National greenhouse gas inventories in boreal forests: The US experience in Interior Alaska

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A national system of field inventory plots is the primary data source for the annual assessment of US forest carbon (C) stocks and stock-change to meet reporting requirements under the United Nations Framework Convention on Climate Change (UNFCCC). The only area of potentially managed forests (i.e., included under UNFCCC reporting) not sampled by the national plot network is the boreal forest of Interior Alaska. The goal of this study was to determine the extent and carbon attributes of managed forest in Interior AK as an initial step towards future full accounting of this boreal landscape. Preliminary results suggest that these forests may represent over a third of all forest carbon in the coterminous US, hence the assessment of their carbon balance is critical in the monitoring of the US terrestrial carbon sink. Furthermore, it is the non-living biomass C pools that may account for the majority of C stocks in this region that may not be adequately quantified using remote sensing products alone. A variety of field and research efforts are currently underway to ameliorate these knowledge gaps which will be discussed in the context of potential future inclusion of interior Alaska's managed forests as part of the US' submission to the UNFCCC.

A1.6

Impacts of climate policies and energy technology paths on the global wood demand and supply

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Three diverse scenarios were defined to examine the supply of and demand for wood biomass under selected energy and climate policies and technological development paths. The global forest sector model EFI-GTM and the global energy systems model TIMES-VTT were used to quantify the market impacts of the scenario assumptions. The analysis of the scenarios sheds insight on questions such as (i) will there be a sustainable and economically feasible supply of wood biomass in the future for the various needs, (ii) what will the competition over resources be like between the countries and various end-use applications of biomass-like liquid biofuels, modern and traditional fuel wood and forest industries, and (iii) what and where are the biggest uncertainties regarding the potential shortage of wood production, e.g., is the additional supply of wood from plantations critical in the long run.

A2.1

Projections of forest productivity under climate change: Uncertainties related to C and N limitation

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There is broad consensus among scientists that the capacity of forests in the boreal zone to take up carbon will increase as a result of climate change and increasing CO_2 concentration. However, boreal forests are strongly nitrogen limited. This could strongly hamper the capacity of forests to benefit from the increased photosynthetic potential. We used OptiPipe, a model of optimal carbon and nitrogen co-allocation to analyse the role of nitrogen availability in growth limitation under climate change in Finland. We predicted changes in metabolic rates related to the C balance using existing models and data, and explored three alternative scenarios of N availability. Three climate scenarios based on SRES emissions scenarios were used for projecting changes of daily climate variables for three 30-year periods in 2011 – 2100 with corresponding CO_2 concentrations. The results were calculated on a 10 km x 10 km grid. The results indicate that NPP and woody growth increase under climate change if the rate of N uptake per unit fine roots is increasing. If this rate does not increase, volume growth is predicted to reduce because maintenance costs increase. Carbon allocation to wood increases is regulated by feedback effects between N availability, foliage biomass and woody growth. If forest management is kept similar to current management, the total biomass of the forest ecosystem will change less than wood production because the residence time of carbon in the ecosystem is simultaneously predicted to decrease.

A2.2

A synthesis of carbon balance of Alaska and projected changes in the 21st Century: Implications for climate policy and carbon management at local, regional, national, and international scales

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Ongoing warming in Alaska has the potential to release carbon to the atmosphere through (1) exposing and mobilizing via permafrost thaw and soil warming the large quantity of organic carbon stored in upland soils and permafrost, wetlands, and surface waters, and (2) emissions associated with potentially more frequent and severe fires. To better understand how carbon responses in Alaska might influence national climate and carbon management policies, the U.S. Geological Survey, in collaboration with the U.S. Forest Service and university scientists, has conducted a comprehensive assessment of the historical and projected carbon balance for Alaska. This assessment of carbon dynamics in Alaska includes (1) syntheses of soil, vegetation, and surface water carbon stocks and fluxes in Alaska, and (2) state of the art models of fire dynamics, vegetation change, forest management, permafrost dynamics, and upland, wetland, and surface water ecosystem carbon dynamics. The assessment considers feedbacks between ecosystem structure/function and fire regime, the dynamics of deep carbon in permafrost, and the mass balance of carbon in and across uplands, wetlands, and surface waters. The information from this assessment is being delivered in a manner that is relevant to the climate policy community and to the community responsible for management of carbon at local, regional, national, and international scales.

A2.3

Resilience in sensitive mountain forest ecosystems under environmental change

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Treeline ecosystems are usually heavily influenced by climatic and land use change, making them useful study objects for describing changes in coupled socio-ecological systems. The concept of resilience of ecosystem services (ES) has been described as the capacity of a social-ecological system to (re) organize itself in order to sustain and enhance the flow of benefits from nature to people in the face of external and internal pressures and trade-offs. Social-ecological indicators measure trends in the factors by which the resilience of ES can be quantified and monitored. By combining the DPSIR (Drivers, Pressures, State, Impacts, Responses) approach and social-ecological indicators, it is possible – by assuming different scenarios – to assess the resilience of ES against environmental changes.

In this paper, the state of ecosystem structures and functions, and changes in selected case study mountain regions throughout Europe were analysed, focusing on the identification of the DPSIR factors and stakeholder needs. The analysis was based on a questionnaire distributed through European research networks. Climate and land use changes were found to be the main drivers, resulting in various pressures on treeline ecosystems which differed among regions. Their impacts were mainly recognized as negative (loss of biodiversity, root rot diseases – moth and bark beetle outbreak, wild fires, decrease of alpine and subalpine grasslands), but also as positive (increase of forested area). The consequences of climate and/or land use changes are discussed in order to provide fundamental knowledge about resilience of treeline ES, as well as on governance and science-society interfaces.

A2.4

Mapping site index: Where are the productive forest areas in Norway?

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What is the expected forest productivity of a given area? The identification of good areas for forest growth is a fundamental question in forest planning strategy, with evident management, logistic and economic implications. Traditionally, site index has been used as a means of estimating the given productivity of a forest area. The present paper focuses on the study of forest productivity in Norway, and aims to develop biologically sound and parsimonious site index models based on spatial methods and boosted regression, with the objective to map site index for *Pinus sylvestris, Picea abies* and birch. The models are constructed using available data from the Norwegian forest inventory, including 3533, 2808 and 2690 plots for spruce, pine and birch, respectively. Special focus was given to the use of climatic variables that would facilitate the identification of climatically sensitive areas, as well as available soil data. The models represented high predictive power: the best model alternative resulted in global R^2 = 0.68, 0.59 and 0.77 for pine, spruce and birch, respectively, although there were important spatial differences concerning their fit. The individual and combined effect of climatic variables was also evaluated. The resulting models and maps can be used as a valuable tool for forest management in Norway.

A2.5

Potential changes in the species’ range of geographical distribution

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Boreal forest vegetation is directly and indirectly affected by climate changes, but we do not know which species are most sensitive to changing conditions and which ones might be good indicators of these changes. In this study, we constructed species-specific response models to environmental factors. We tested the hypothesis that temperature prevails to determine species’ abundance and that biotic interactions and other environmental factors do not change the predicted climate response of major understory species. We used Finnish nationwide vegetation abundance data from 3000 sample plots and soil data from a sub-sample of the plots for modelling plant species’ responses to environmental variables. Historical climatic data and future climate predictions were obtained from the Finnish Meteorological Institute on a grid scale of 1 x 1 km^2 and 10 x 10 km^2, respectively. First, we prepared statistical models (95%-quantile regression models) to explain species’ abundance along a temperature gradient, and compared models including only temperature and models including also other environmental variables. Second, we tested each model’s predictive accuracy with historical data on species abundance and temperature. Finally, we derived future spatial predictions of species potential distribution across Finland for a set of focal species that meet the requirements for trustable predictions (reliability of temperature-only models and good predictive accuracy demonstrated on historical data). We predicted major changes in the range of geographical distribution for many understory plant species. In addition, we identified a set of potential indicator species that could be used by the national forest inventory or by citizen science for the monitoring of the effects of climate change.

A2.6

Regional assessment of forest carbon budget (ROBUL): An open source tool for analysis of Russian State Forest Registry databases

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The system of regional assessment of forest carbon budget (ROBUL) is developed as a tool for analysis of the State Forest Registry (SFR) databases. SFR of the Russian Federation is a national-level compilation of local forest inventory data. SFR contains information about areas and growing stocks of different forest types, separated by dominant tree species, age groups, commerce and protective characteristics. The ROBUL system includes sets of equations and parameter tables which allow quantitative interpretation of SFR data in carbon units. Specific sets of conversion factors are used to calculate carbon in biomass and dead wood based on growing stock values. Sets of typical values per area unit are used for estimation of soil and litter carbon pools based on the area information. SFR data, separated by age groups, are used for producing ”carbon growth curves” and the subsequent assessment of carbon increments. Carbon losses due to forest felling, forest fires and other destructive disturbances are estimated using the information on clearcuts, burnt and dead forest areas from SFR. The alternative way to estimate carbon losses is based on using officially reported volumes of harvested wood and remote sensing data on forest fires. The carbon budget is calculated as a balance between increments and losses. Uncertainties’ estimates are based on errors of conversion factors and typical values. The ROBUL system is used in the Russian official GHG inventory and generates data for UNFCC reporting. ROBUL software is available for open use through Internet.

A2.7

Model simulations of the climate change effects on soil physical conditions in Finnish Lapland

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Climate change will affect boreal forest ecosystems both above and below the soil surface. The use of ecological models allows researchers to study the possible impacts of climate change on growth factors such as soil temperature, water content and air-filled porosity. We calibrated the CoupModel to 32 soil profiles representing four till soil types (USDA): sand, loamy sand, sandy loam and silt loam. The simulations were made without vegetation effects for open areas with a flat terrain. Thirty-year climate data from Sodankylä in central Finnish Lapland and the respective climate change scenario data were used in the simulations. According to the simulations, climate change will prolong the snow-free period and decrease the snow cover. The effects are more evident in spring. The snowmelt peak in soil moisture will be weaker and occur even a month earlier than in the present climate. The thinner snow cover results in thicker ground frost, which may cause problems for the forest vegetation in the warmer spring climate. The growing seasons will also lengthen more in the springtime than in autumn. Soil water content and air-filled porosity during the summer months will not radically change in the future. However, during rainy summers the air-filled porosity of 20% needed for good root growth of conifers will occasionally not be reached in fine-textured soil types, and the occurrence of such days will increase due to climate change.

A3.1

Large-scale mapping of forest structural parameters in Norway: Combining 3D image matching point clouds, NFI plot data, and existing land use maps

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The demand for regularly updated localized data on forest parameters for relatively small units, such as counties or municipalities, has increased. In the project Forest Mapping and Planning (ForestMAP), we combined existing land use maps, NFI plots, and 3D aerial image matching point clouds to map various forest parameters such as forest boundaries, timber volume, forest productivity, and tree species. We present the results from our pilot study area, a 16000 km^2 part of Norway covering most of the county of Nord-Trøndelag. We show that decade-old existing forest boundaries can be efficiently updated using the available data and appropriate algorithms. For most of the standard forest parameters, the accuracies were slightly lower than commonly obtained with airborne laser scanning but in the same range. However, the cost of the image matching point cloud is much lower than that of laser scanning.

Based on the results of the pilot study, it is planned to implement the developed approach at a national scale. Aerial images in Norway are annually captured for approximately 1/5 of the country. The developed approach will be applied step-by-step for all of Norway as the availability of image matching data increases. The challenges arising from a large-scale project resulting in solutions ranging from software to estimators are discussed.

Local forest management inventories (FMIs) are carried out in Norway to provide detailed stand-level forest data. Here we discuss how the developed regional maps may be used in local FMIs.

A3.2

Forest Big Data – basis for the next generation forest inventory system

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The objective of the Forest Big Data project is to provide the basis for the next generation forest inventory system. Increasingly accurate and diverse information on Finnish forests is needed in the future to meet the needs of the forest sector. More accurate data can be used to increase the value added of wood raw material and to increase the cost efficiency of timber logistics, the profitability of timber production and environmental management. Highly precise forest resource data is an integral component of the infrastructure of the developing bio-economy, and it will benefit all players in the forestry sector value chain.

One of the key research tasks is to develop cost-efficient methods based on new technologies that help generate more detailed data on stand and harvest conditions. The main objective is to produce a tree species-based distribution of stem size and quality data, as well as soil condition identifiers for the basic unit, i.e.. grid of forest resource data inventory. For this purpose, various remote sensing and terrestrial tree mapping methods as well as data gathered from forest operations and production will be tested.

In the project, the focus will also be on developing an aggregation method to combine information gathered from various sources, outlining the system architecture, testing key application concepts as well as analysing business opportunities related to Forest Big Data. The project will involve all of Finland's largest forest companies and Metsähallitus, the main research actors, and a number of system suppliers and other productising businesses.

A3.3

Approaches for estimating key figures on stand-level from terrestrial laser scanning in a single-scan mode

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The most efficient way to obtain stand inventory data with terrestrial laser systems (TLS) is with the single-scan mode, which involves taking one scan at a single point. With a single-scan setup, there will be a nondetection of trees in a plot and the representation of the individual trees will be incomplete.

We explore how stand-level estimates of volume, tree number and basal area, based on the single-scan mode, perform compared with standard inventory estimates in mature stands dominated by Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* L. Karst) in southern Norway.

We test different approaches for correction of nondetection relying on model-based estimates of the detection probability obtained by point transect sampling estimators. We show that all approaches adjust for nondetection and yield stand-level estimates that are similar to those obtained by fixed-area sampling. In conclusion, our results indicate that stand-level estimates, based on single-scan mode TLS data, perform well compared with standard inventory estimates.

A3.4

Random point process models with hierarchical interactions improve spatial tree pattern analysis in forestry

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Spatial relationships between trees play a fundamental role in forest ecosystems and their dynamics, governing together with other factors interaction, growth, mortality and regeneration processes of a plant community. Therefore, the study of spatial relationships, i.e., spatial structure of a forest stand, is of great interest in plant ecology. It allows advancement of our understanding of underlying ecological processes by testing hypotheses in a more refined way. However, the consideration of spatial dependencies is comparatively new, and only recently have advances in point process statistics and modelling of the last 3 – 4 decades allowed us to explore this field of quantitative ecology.

When studying a forest or plant community, spatial and temporal aspects are tightly coupled: Spatial patterns are the result of past ecological processes and temporal changes of individual trees depend on other trees and can therefore not be considered as independent units. Both temporal and spatial relations between trees can be captured under modelling by hierarchical interactions. We considered a hierarchical structure of interactions to account for the fact that competition for light is size-asymmetric. Unlike previous approaches, the new spatial model has the advantage of allowing a straightforward interpretation of its parameters in terms of inter-tree competition. According to the analysis, the random point process models with hierarchical interactions have the required flexibility to capture complex spatial tree patterns.

A3.5

Data assimilation in stand-level forest inventory – first results

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As we are entering an era of increased supply of remote sensing data, we believe that data assimilation has a large potential for keeping forest stand registers up to date (Ehlers et al. 2013). Data assimilation combines forecasts of previous estimates with new observations of the current state in an optimal way based on the uncertainties in the forecast and the observations. These forecasting and updating steps can be repeated with new available observations to get improved estimations. In the present study, we use canopy height models obtained from matching of digital aerial photos over the test site Remningstorp in Sweden, acquired 2003, 2005, 2007, 2009, 2010 and 2012 and normalized with a DEM from airborne laser scanning. Stem volume was estimated for each data acquisition and stand, using regression functions based on field reference data from sample plots. Forecasting was done with growth functions constructed from National Forest Inventory plots. The remote sensing estimates for each time point were assimilated with the forecasts of the previous estimates, using extended Kalman filtering. Validation was done on 40 m radius sample plots dominated by Norway spruce. Early results for three stands show that the variances were lower when using assimilation of new estimates and there was less fluctuation compared to repeated remote sensing estimates. The results for the assimilated data at year 2011 were also consistently closer to the validation data measured in 2011 compared to the remote sensing estimates from year 2011.

A3.6

The prediction of single tree biomass, logging recoveries and quality attributes with laser scanning techniques

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The precise knowledge of biomass, logging recoveries and quality of the available timber plays an essential role in decision-making, forest management procedure planning and wood supply chain optimization. The ability to directly measure the 3D structure of the forest vegetation has been a key turning point in remote sensing-based forest mapping applications. We have concentrated on developing laser scanning (LS) -based methodologies for mapping of single trees. We have developed new high density LS-based models and methodologies for aboveground biomass, logging recovery, stem curve and quality estimation. We have also introduced multisource methodologies for next generation's detailed forest inventory process. Results indicated that terrestrial LS (TLS) is a vital option for measuring the following single tree-level attributes: (1) tree biomass, (2) timber assortments, (3) timber quality and (4) stem curve. TLS-based biomass models significantly improved the accuracy of component-level AGB estimation. Results in timber assortment estimation were promising especially for the most valuable part of the tree (saw wood). Tree quality is an important factor for accurate and successful timber assortment estimation and it can be measured with TLS. The automatic stem curve measurement technique was demonstrated to be effective and accurate and it could be utilized to make TLS measurements more efficient in the future. The multi-source single-tree inventory approach provides a new and practical approach combining high density LS techniques for forest preharvest measurements.

A4.1

Multi-source data fusion methods for tree stands in a forest big data platform

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In this paper, we consider a forest big data platform utilizing all available data sources with varying spatial granularity and up-to-datedness, aimed at providing an up-to-date estimate on tree stand or individual tree properties, such as diameter, height, and quality. In the system architecture, the platform operates between data sources and applications, defining the communication interfaces, and in particular the data structure required for the data sources to connect to the system and to be utilized in data fusion.

In the data structure, grid-level data is a list of attribute values associated to grid cells capturing the stand characteristics together with covariance matrix specifying the attribute uncertainties related to the observation. Tree-level data is a list of property values together with the covariance matrix.

The platform implements a Bayesian filter by predicting the data sources up-to-date with growth models and then fusing the information by utilizing the uncertainty information. The data fusion is considered at grid level for a set of trees inside the grid cells, producing estimates on property distributions, such as the diameter distribution. At tree level, data fusion produces estimates on properties of individual trees, such as diameter.

Estimates provided by the platform can be used with forest simulators for studying the effects of forest management actions and scenarios on forest growth and yield. Applications related to forest planning, trading, harvesting and transportation, and production can be built on top of the platform to enhance the utilization of forests resources with the up-to-date and accurate forest estimates.

A4.2

A new approach to NFI data integration for international forest resource assessment

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Countries maintain National Forest Inventories for strategic monitoring of forests at national and sub-national levels. NFI data are used to generate national-level statistics for the FAO's periodic Global Forest Resource Assessments. While the data collected by FAO are of great value for global forest resource assessment purposes, aggregation according to ecological strata rather than by country provides the possibility for more in-depth assessment of regional sustainable forest management successes and challenges, especially for large countries that span multiple biomes. Such aggregation requires a deeper level of data harmonization across political borders. The North American Forest Commission's Inventory and Monitoring Working Group (IMWG) piloted this approach by developing an infrastructure for NFI data harmonization and analysis with three basic elements: (i) North American NFI data harmonization rules, (ii) a harmonized North American ecoregion map, and (iii) a relational database for managing integrated North American forest inventory data from the United States, Mexico and Canada. Could this approach be extended to include other boreal countries and enable pan-boreal forest inventory data integration for biome-level forest assessment?

A4.3

Reconstruction, quantification, and visualization of forest canopy based on 3D triangulations of airborne laser scanning point data

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A technique to reconstruct three-dimensional forest canopy from sparse-density airborne laser scanning (ALS) data (< 1 observations per m^2) is described and quantified using field measurements aggregated at resolutions of 250 – 1000 m^2. The reconstruction is based on computational geometry, topological connectivity, and numerical optimization, and more specifically on analyzing triangulations and their filtrations, i.e., ordered sets of simplices belonging to the triangulations of the ALS point data. Triangulating point data corresponds to subdividing the underlying space of the points into weighted simplicial complexes with weights quantifying the (empty) space delimited by the points. Reconstructing the canopy volume populated by biomass will thus likely require filtering to exclude that volume from canopy voids. The approaches applied for this purpose were (i) to optimize the degree of filtration with respect to the field measurements, and (ii) to predict this degree by means of analyzing the persistent homology of the obtained triangulations, which is applied for the first time to vegetation point clouds. When derived from optimized filtrations, the total tetrahedral volume had a high degree of determination (R^2) with forest biophysical attributes measured in the field. When derived by analyzing the topological persistence of the point data and without any field input, the R^2 values were lower, but this approach is nonetheless suitable for producing realistic visualizations of a forested landscape, for example. The implementations were based on efficient data structures and are computationally feasible for practical applications.

A4.4

Satellite-based estimation of boreal forest fPAR

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The fraction of absorbed Photosynthetically Active Radiation (fPAR) is one of Essential Climate Variables (ECVs) and may be used to estimate forest productivity. Estimates of fPAR can be retrieved from satellite-based measurements. Currently, there are only coarse spatial resolution (1 km^2) fPAR products available, which are not suitable for monitoring or modeling stand-level processes (1 – 2 ha) in fragmented landscapes such as Finnish boreal forests. Therefore, fine spatial resolution fPAR data are needed. Vegetation indices (VIs), which describe the structure and functioning of green vegetation, are calculated from satellite reflectance data and can be applied to data from different satellite sensors and different spatial resolutions. For example, the most well-known vegetation index, the Normalized Difference Vegetation Index (NDVI) has long been used to quantify the amount of vegetation. Even though different NDVI-fPAR relations have been used to estimate fPAR of different biomes, very few studies exist for boreal forests. Also, it is not clear which other vegetation indices besides NDVI are suitable for estimating boreal forest fPAR. In this study, we used fine resolution satellite-based data and different VIs to estimate fPAR of over 1000 stands in southern Finland.

A5.1

Conservation biologist needs to take a more active interest in interest rates: Linking economic drivers to habitat availability in production forests

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Because of the limited spatial extent and comprehensiveness of protected areas, an increasing emphasis is being placed on conserving biodiversity within production forest areas. Therefore, decisions regarding the management of production forests need to be assessed in terms of their resultant implications on forest biodiversity. Management decisions in production forests are strongly influenced by socio-economic drivers operating well outside the boundaries of the stand, whereas conservation interventions often occur as responses to such decisions. In this study we examined the economic determinants of habitat availability in production forests, by simulating the effects of interest rate variation on thinning programs and the rotation lengths of four Swedish production forest systems. Interest rates can alter thinning and harvesting decisions by changing the relative value of future wood-sale profits to forest owners. Our results demonstrate the extent to which higher interest rates can decrease rotation lengths, and correspondingly reduce the availability of large living trees and the quality and quantity of dead wood. Our results also demonstrate that the capacity of conservation interventions (e.g., retention trees) to adequately compensate for such losses will likewise vary with interest rate changes. If conservation biologists and policymakers take into account the capacity of economic drivers to alter habitat availability within the production forest matrix, their conservation interventions would be more effective and long-lasting.

A5.2

Regional and agent group welfare impacts of forest climate policies

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Forests are an important part of the natural carbon cycle, and offer substantial opportunities for climate change mitigation through enhanced carbon sequestration of existing forests and reforested land, and via more substitution of fossil fuel-based energy carriers and materials. There is an ongoing debate regarding which part of the forest sector (i.e., forestry, forest and bioenergy industries) should be targeted by climate policies in order to be cost-effective. However, other aspects of policies are also of interest, such as distributional impacts across geographical areas and groups of agents. In this study, we compare a set of policies with regard to climate change mitigation cost-effectiveness and distributional impacts across regions and groups of agents in the forest sector. Policies include carbon tax/subsidies to forests and the whole sector and subsidies to bioenergy and solid wood consumption. Norway, with vast forest resources and well-developed forest and bioenergy industries, is used as a case study. We utilize a partial equilibrium model of the Norwegian forest sector with detailed data to simulate forest management and growth, harvest, wood processing, consumption, trade, greenhouse gas fluxes and albedo effects for 19 counties over the next century. The results provide insight for policy-makers designing climate change mitigation policies in forest-rich countries.

A6.1

Soil organic carbon stocks and changes in Norwegian forest ecosystems

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The amount of soil organic carbon (SOC) in Norwegian forests is estimated to be approximately three times that found in living trees. The need to develop and test models for the prediction of this large stock as well as its dynamics is apparent. Predictions are needed for both greenhouse gas reporting and scenario evaluation of forest policy strategies. A soil survey was carried out on a total of 1040 plots across Norway. In this study, we compare measured and model-based SOC stocks on ca. 800 upland forest plots in the Norwegian NFI using the Yasso07 model. While substantial uncertainty in both soil survey data and model input and parameters are to be expected in all regions, the discrepancy varies by region, soil type and climate and overall the simulated SOC stocks are low compared to the estimates based on soil survey data. Here we aim to quantify the importance of factors potentially explaining the observed discrepancies (residuals). Specifically we test the hypotheses that i) residuals are largest for regions with high precipitation, ii) residuals depend on drainage and soil type, iii) residuals depend on vegetation (tree species). SOC changes are difficult to measure due to substantial within-site and between-site variation. Observations of changes in the SOC stocks are not available for Norway at the national scale. Still, we show Yasso07-simulated changes and relate them to climatic conditions, litter quality and soil physical and chemical properties.

A6.2

Peatland ecosystem resilience and resistance under forestry: Focus on soil carbon

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The ”peatiest” regions of the world are found in the boreal zone, where peatlands are an integral part of the landscape. Like all natural resources, peatlands have long been used by man. Currently, the areally most important land use in the boreal zone is forestry. Altogether, at least 10.5 million ha have been drained to improve forest growth. Most of this area is in northern Europe. Drainage aims to lower the water level, thus extending the rooting zone and improving its oxygen status, and increasing tree growth through improved root functioning.

Peat accumulation and storage are facilitated by slow rates of decomposition of organic matter that has reached the anoxic zone, either after having experienced aerobic decomposition in the oxic layers, or having been formed directly in the anoxic layers. Persistent lowering of the water level logically poses a threat for the carbon storage function. Aerobic decomposition may now proceed further in the more extensive oxic layer. Simultaneously, however, other structural features and processes also change. For instance, pore size distribution, water retention capacity, pH, and bulk density of the peat change. Also, the new hydrological conditions initiate a vegetation succession. Consequently, the quantity and quality of litter inputs change.

All these changes affect the exchange of CO_2 between soil and atmosphere. Our aim is to review how the changes in vegetation and surface soil properties are reflected in the resilience and resistance of peatland ecosystems under forestry use. Our main focus is on the carbon accumulation and storage functions.

A6.3

Tree species effect on soil carbon sequestration

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During pedogenesis, plants actively alter soil as a medium for plant growth through input of species-specific organic matter. To understand the effect of tree species on soil organic matter sequestration, we study interaction between separate tree species and soil properties in a common garden experiment, where tree stands develop under similar initial soil, climatic and ecological conditions.

Our research was carried out on the long-term Siberian Afforestation Experiment that was established in 1969 – 1972. The research plot is located 50 km northwest of Krasnoyarsk, Russia (56°13’ N, 92°19’ E). Monoculture stands of Siberian pine, Scots pine, larch, Siberian spruce, aspen and birch grow on the Greyic-Luvic Phaeozems.

Recently, at the age of 40 significant increases in forest litter and mineral soil carbon stocks were observed. Mineral soil carbon in the 0 – 20 cm layer increased by 12 – 44% over the last 40 years. The maximal increment of mineral soil carbon stock was observed in the uppermost 0 – 5 cm layer.

We suppose that different mechanisms are responsible for soil organic matter accumulation under the different tree species. The most significant accumulation of mineral soil carbon was observed beneath the spruce stand, which had the highest rate of fine and small root turnover as well as the most significant decrease in soil pH over the last 15 years. High mineral soil C accumulation beneath the larch stand was probably a result of litter decomposition and dissolved organic matter migration.

This research is supported by the Russian Fund of Basic Research (grant № 13-04-01128).

A6.4

Carbon loss in forest soils due to soil tilling: Studies at clearcut margins of old-growth forest stands in middle and northern boreal forest zones in Finland

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Effects of forest soil tilling on its carbon content were studied at sites where an old natural forest stand is bordered by a modern clearcut. The study sites were selected from aerial photographs so as to represent the various mineral soil (podzol) treatments customarily applied in Finnish forestry (ploughing, harrowing, scarification, or no soil preparation). Most of the sites were located at the margins of nature protection areas; in northern Lapland some strip-felling sites were also included. At each site 20 + 20 topsoil cores were taken with a 10-cm^2 sampler, typically along 40-m transects from both the pristine and treated sides. The samples were dried (+105°C), weighted, milled and incinerated (+550°C) to determine their organic matter (OM) content.

A statistically significant decrease in OM content was observed in more than half of the soil treatment sites. The average OM at the pristine sites was 7.5 kg OM m^{-2}, while an overall decline of some 20% was seen at the treated sites (ranging from slight increase to loss of 59%). As for clearcuts without soil treatment, preliminary results indicate comparably lesser losses, but the study is still in progress.

The results should raise some concern about the alleged climate neutrality of the intensive forestry currently practiced in Finland. Annually, some 100000 to 150000 hectares of mineral soils are variously treated, and thus far, at least 30% of forest soils have been manipulated.

A6.5

Buried dead wood: examining the prevalence, process, and implications for national forest inventories

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As dead wood can represent a substantial portion of forest ecosystem carbon stocks, it is often reported as its own pool following good practice guidance associated with national greenhouse gas inventories. In numerous high latitude forest ecosystems, such as those typified by boreal forests, a significant proportion of the dead wood carbon pool is overgrown by ground vegetation and buried in the humus layer.

Data from Norwegian and Swedish national forest inventory plots show that very few downed logs become buried in temperate broad-leaved forests whereas this is very common in boreal coniferous forest. Across the boreal region from south, to mid-zone, to north, the frequency of wood burial appears to increase then slightly decrease, respectively. Several factors affect the probability of burial, including log properties (especially decay class), ground vegetation (e.g., moss dominance), and edaphic conditions (e.g., organic soils). Combined assessments suggest that about 20% of the carbon in the above-ground dead wood pool becomes buried in boreal forests. This has important implications for forest carbon sequestration since buried wood typically decomposes much slower as compared with above-ground dead wood.

National forest inventories represent an important data source for quantifying the frequency of dead wood burial as well as the duration from initial coverage to complete burial across stand conditions. A standard methodology is suggested to document wood burial to benefit biomass/carbon accounting across national forest inventories in boreal forests.

A6.6

Carbon and nutrient cycling in pine forest in western Siberia as affected by gas flaring

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Climate warming and industrial atmosphere fertilization with additional CO_2 are known to affect functioning of terrestrial ecosystems. In the last decades, a number of manipulation experiments have been established throughout the world to simulate the potential climatic impacts. In our research, we used a forest ecosystem located near a gas torch as a kind of manipulation experiment to assess the synergistic effect of warming and CO_2 fertilization.

The experimental plots were established in western Siberian, young Scots pine forest (координаты) on sandy podzolic soil at three distances of 70, 90 and 130 m from the torch, with trees exposed to strong (S), moderate (M), and weak (W) impacts, respectively.

Shifts in soil temperature in summertime were moderate: on average 0.7°C and 1.3°C for the plots M and S, respectively, compared to the plot W. Also, the wetness of the soil in plots S and M was lower by 1/10 – 1/5 than that of plot W. We found intensification of photosynthesis, soil basal respiration, enzyme activity and concentrations of nutrients and soil microbial biomass in plot S compared to plots W and M. The isotopic signature of 13C in pine needles showed that the effect of warming on pine growth was more prominent than the impact of CO_2 fertilization by gas combustion.

The research was supported by the Alexander von Humboldt Foundation, the Russian Foundation for Basic Researches, Presidium of the Russian Academy of Sciences (Program no. 4), and the grant no. NSh-6123.2014.4.

A7.1

Data-driven animation, interactive 3D models and social media in forest research

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For about two years, our research team at Tampere University of Technology has been disseminating research results in the form of animations, interactive 3D models and Facebook updates. The animations showcase how the methods we have developed can be used to reconstruct tree models from terrestrial laser scanning data. The computations are done in Matlab, and the results are exported to Blender – an open-source 3D modeling and animation software – to make data-driven animations that are later uploaded to the group's YouTube channel and further shared on our research consortium's Facebook page. Some of the resulting models have also been published as interactive 3D models that can be viewed in a standard web browser supporting WebGL technology. The extensive, positive feedback has shown that these innovative dissemination channels are vital for helping others understand the research methods and results without getting lost in the details.

The 3D Forest Information video introduces the reconstruction procedure at a very simplified level, and concentrates on the resulting 3D models and the derived, valuable information. The point cloud data, cylinder models and the model properties were all exported from Matlab. This process could be automated to the extent that a similar video could be done automatically without user interaction, as could the creation of interactive 3D models. Automating the process would allow, e.g. the creation of a tree database storing the structure information as well as the visualization of individual trees and forest plots.

A7.2

VIDEO: How to make a bee hotel

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Bees are essential in the pollination of plants. This video tells you how to make a bee hotel. Bee hotels are made for solitary bees and potter wasps because agricultural changes have reduced the number of good nesting places.

This video was made in the project called Bees & Biodiversity. One of the local activities in Kainuu, Finland was raising awareness to which this video was related.

The project was funded by the European Agricultural Fund for Rural Development: Europe investing in rural areas.

The link to the video is: http://youtu.be/mXeOUSLGBg8 or you can find it on YouTube (search word: 'How to make a bee hotel - Pölyttäjien keinopesän valmistus').

A7.3

The Generation X Science Centre as an innovative means to communicate science – case Pilke

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A Science Centre is one of the key means to communicate science, its possibilities and future adaptations to wider audiences. However, too often we think of science centres just as buildings, institutions and places to visit. The core points of discussing science-based issues, Doing together, Learning by doing, and thus Crafting knowledge together, are applicable to any location and environment.

In our educational and action-based forest area Mottimetsä, pre-organized groups can enjoy expanded Everyman's rights and experience the forest in an active way. Our touring pop-up Science Centre, The Forest Arcade, is an innovative wooden structure hosting various forest-related games and activities and has been touring several events and locations starting from the annual Forest Fair event in Helsinki. In the coming years, it will visit all over Finland.

Science Centre Pilke itself and its exhibition are, of course, the central surroundings to welcome visitors, school groups and workshop attendees, being a place of spatial communication where all the details communicate the same message. The different exhibition demos encourage visitors to get active and discuss the different themes together. We also hold most of our workshops within the exhibition instead of separate labs or classroom activities. It is an educational environment in itself. It has also hosted numerous events and seminars, and we welcome our partners to co-operate and use Pilke for their own activities. Pilke is best enjoyed with company!

A7.4

Science and arts are two profound forces shaping our past and present-day reality

Antti Tenetz

Tenetz, Oulu, Finland

Revolutionary change in the development of technologies and how our life dwells in technologies affect our ways of observing and producing experiences and information, the digital, technological and biological materials of our environment. We will present two art/science projects as case studies for innovative approaches that combine science, arts, communication and design.

Cool Experts

The transmedia project presents researchers of the Arctic Centre of the University of Lapland and issues related to Arctic regions. The project explores the personality and biography of selected scientists through their personal stories in order to make research questions and fields understandable to a wider public. Media include video, photography, interactive maps, articles and timelines. The transmedia presentation is available online and as an applied version in the exhibition of the Arctic Science Centre, Arktikum, in Rovaniemi, Pohjoisranta 4. www.coolexperts.fi

Jälestää-Tracing

Tracing is a continuous work examining the relationship between animals and human beings and their positioning in their own living environment through their traces, movements and actions. An art/science exhibition and website integrate multi-layered data of animals and landscapes. The work is based mainly on Luke's data on wolves and trout in Lapland. It consists of video materials done underwater and in the air with drones, photos and visualisation of data derived from GPS collars. The installation uses state-of-the-art laser and led technologies. The work has been exhibited in the Oulu Art Museum's Leonardo exhibition in January – March 2015 and partly in the exhibition Distant Yet Connected at 643 project Space, Ventura, California. www.tenetz.com/JALESTAA

A8.1

Quantification and valuation of ecosystem services to optimize sustainable re-use for low-productive drained peatlands

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More than half of the original peatlands have been drained in Finland to increase tree growth. However, 20% of the drained peatland area is low-productive, and does not produce enough timber to fulfill commercial purposes. At the same time, their biodiversity is degraded, they may continue environmental loading to watercourses, and act as greenhouse gas (GHG) sources. A key question concerning the use of peatlands in Finland is what to do with these low-productive drained peatlands that have been left aside from active forestry.

These low-productive peatlands can be re-used in many different ways. The problem is that the impacts of different re-use options on biodiversity, environment and economy are not yet fully understood and thus it is hard to give proposals for re-use actions. The challenge is to develop mechanisms that can balance the conflicting demands on the use of peatlands and to ensure their sustainable use. Our 5-year EU funded LIFE+ project LIFEPeatLandUse (2013 – 2018) consolidates the knowledge on the impacts of peatland re-use on ecosystem services. Under investigation, there are seven different peatland re-use options, representing economic activity as well as measures related to protection. The purpose is to evaluate and predict their potential impacts on the peatland landscapes, if they were applied in practice. The aim is to find cost-efficient re-use options for low-productive drained peatlands, which help to prevent or stop the decline of biodiversity and environmental loading to watercourses, and improve the capacity of peatlands to store greenhouse gases.

A8.2

Forest management certification – application of a new tool for certification mapping to the boreal forest

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During the past decades, forest management certification has become a tool to support a transition to and ensure sustainable forest management. However, the speed of certification has slowed down and the certified area is unevenly distributed with the majority located in the Northern Hemisphere. To date, there is insufficient empirical evidence on the impacts of certification to generate lessons learned on a global scale. While several published reviews of forest management certification provide some guidance for future work, most were based on geographically limited case studies, indirect information, and were not conducted by independent observers. This article's objectives are 3-fold: a) it aims at the improvement of existing statistical and spatial information by providing a methodology for assessing the global certified forest area with special emphasis on the boreal domain; b) to provide support to science and certification schemes with respect to impact assessments, support of strategies of future certification development and investments, and identification of hot-spot areas where, e.g., some promotional activities might drive and/or accelerate certification; c) the article investigates how certification can contribute to the planning of other policy strategies, e.g., aimed at biodiversity conservation, REDD+, conservation of, e.g., intact forests, and provision of science-based policy recommendations. It is demonstrated that the new tool allows the localization of certified forest area, actively distinguishing between managed and unmanaged forest areas. It also allows for localization of areas with large co-benefit potential. Knowledge of certified forest locations is also key to developing certification into a monitoring and verification tool.

A8.3

Securing forest ecosystem services in Finnish state-owned multiple-use forests managed by Metsähallitus

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Metsähallitus manages about a third of Finland's commercial forests. These are vibrant forests used for various purposes, not just to produce wood, but also for recreation and preserving biodiversity. Other important purposes include landscape, game animals, water protection, cultural heritage and, in northern Finland, reindeer husbandry. Using an up-to-date all-inclusive GIS in various phases of operational planning ensures that these special values are taken into consideration when utilising the forests. Significant forestry operations and other activities with substantial effects on reindeer herding are negotiated with the relevant reindeer herding co-operative.

Means of safeguarding biodiversity include retention trees and excluding valuable habitats from forest management activities, or treating them carefully considering their special nature through for instance mature thinning, retention felling, uneven-aged methods and gap felling. In a conifer stand, the proportion of broadleaves is retained at 10 – 30%. During the growth phase, small thickets are left untouched and unnecessary clearing of undergrowth is avoided. Standard water protection measures include, e.g., buffer zones in felling and site preparation areas.

The environmental performance of forestry, like the amount of retention trees, buffer zones, preservation of valuable habitats, etc. are surveyed annually. On average, about 15 retention trees corresponding to 9 – 10 cubic meters of wood per hectare are left on regeneration sites. More than 95% of the valuable habitats are well preserved after regeneration fellings. Training needs and refinement of forestry operations are based on the results of environmental surveys.

A8.4

Wildlife monitoring in Finland – on-line information to game administration, hunters and wider public

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Annual nationwide monitoring of grouse (hunted tetraonid birds) began in Finland in the beginning of the 1960s and systematic counts of mammal snow tracks started in the late 1980s. The so-called wildlife triangle scheme is based on a large number (around 1700) of transect lines covering the entire country. Wildlife triangles of 12 km each constitute permanent transects founded on forest land. The program involves an astonishing amount of fieldwork. Most of the heavy fieldwork is performed by trained volunteers, mainly hunters.

The former Finnish Game and Fisheries Research Institute launched an internet service for the 2014 late-summer count. Via the internet, census-takers can record their observations in a database and follow the progress of the count during the fieldwork stage.

The internet service is a significant innovation since it speeds up the collection of observations, simplifies data storage and assists in the creation and sending of reports. Feedback is now delivered to census-takers much faster, who are also able to search for information from the database themselves.

Data provided by the wildlife triangle scheme is utilised by the EU, the Ministry of Agriculture and Forestry and other game administrative bodies, as well as hunting clubs and the public. Annual late-summer count results from wildlife triangles are used immediately when deciding on restrictions to the forthcoming grouse hunting season, due to begin just a few weeks later. The presentation demonstrates how information can be obtained from the database for various purposes.

B1.1

The role and impacts of fire in the boreal zone: Status of knowledge and implications for the future

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Research conducted over the past several decades has greatly changed our understanding of the extent, patterns, and impact of wildfire in the circumboreal zone. The availability of remote sensing data and field data on fire behavior and fire regimes, forest carbon, vegetation and fuels at various scales has been essential to improvements in estimates of burned area, fuel consumption, fire emissions, and impacts of fire on ecosystem processes and carbon stocks. Analyses of atmospheric circulation patterns are helping us to understand seasonal and interannual patterns and trends in occurrence of large-scale fire events. Dendrochronological and paleoecological data on fire and climate in selected regions is providing information on fire-climate interactions over centuries to millennia. In this presentation, we discuss the perspectives gained from historical data, field research and remote sensing data on past and current fire regimes, and how this knowledge helps us better understand potential impacts of changing climate on fire regimes. We will discuss some of the sources of error in characterizing past and present fire regimes and their feedbacks to the climate system, and outline the most important ongoing research needs.

B1.2

Canadian boreal forest timber vulnerability to current and future fire risk

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Forest fires are important disturbances affecting timber supply in Canada's boreal forests, and the area they burn is predicted to increase with climate change. We explored how such changes would impact the timber supply by Forest Management Areas (FMAs) by computing FMA-level estimates of timber supply vulnerability to fire risk. Using MODIS-based Canada-wide maps of forest properties, empirical yield functions were created and used to determine the time required for stands to reach a given threshold of commercial volume, and the resulting FMA-level potential yearly harvest rate whose value was reduced through the insertion of the current and future values of fire risk for time periods up to 2071 – 2100. We used a second MODIS-based Canada-wide product of yearly harvests to determine the current yearly FMA-level harvest rates. The ratio of current to potential harvest rates was used as an index of vulnerability. Our results show that a large portion of the Canadian boreal forest has a high projected vulnerability to fire under future predicted fire regime, and that this vulnerability is likely currently present at a moderate level in these areas. Sensitive FMAs are generally where growth rates are low, harvesting activities are important, and fire activity is already important and predicted to increase in the coming decades.

B1.3

Assessing forest vulnerability to fire risk and its potential impact on forest management planning

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The main objective in timber supply is the achievement of sustainable forest management, but achieving this goal requires the incorporation of risk and uncertainty into long-term planning (150 years). Understanding where vulnerabilities lie is important in forest management, such as the vulnerability of landscapes to fire, which needs to be considered when undertaking forest planning. The goal of this study was to estimate the production of timber supply by excluding stands considered vulnerable to fire under the current harvesting thresholds and fire cycle. In order to improve the decision process of excluding vulnerable stands from the timber productivity, we built a scenario combining the fire occurrence process and the harvest schedule to evaluate quantitative fire survival likelihood probabilities set at 66%, 50% and 33%. We used fire cycle lengths representative of the historical and future fire cycles reported for the study area (400, 200 and 100 years) and the assumption that the harvest takes place at the optimal stand harvesting threshold of 60 m^3/ha. The estimates have been used to change the probability of loss in AAC when different percentages of forest stand species that are particularly vulnerable to fire are excluded. The results from these analyses were used to advocate a decision-making framework for managing risk based on an understanding of stand vulnerability to the present and future fire regime. From this understanding, the viability of the harvest schedule could be determined.

B1.4

Long-term remote monitoring of wildfires in Siberia

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Satellite data are an important component of the wildfire monitoring system in Russia, where most of the boreal taiga is under satellite observation. Results will be presented for wildfire satellite monitoring in the forests of Siberia during 1995 – 2014. Long-term statistics, trends and prognosis of wildfire activity will be presented for the Siberian forests under the modern climate regime and human activity.

The main aspects of our investigations are:

- spatial and temporal distributions of mass or large-scale wildfires in Siberian forests;
- assessments of TERRA/Modis-derived Fire Radiative Power (FRP) for different types of wildfires and FRP dynamics analysis as well;
- quantitative assessment of impact for different categories of wildfires in terms of size and radiative power.

As new attributive information on wildfire, we investigated the radiation power of wildfires by using TERRA/Modis data in 4 mm spectral band. Fire Radiative Power has been used for calibrating the high-temperature event database. We produced the classification of wildfires based on FRP values. Validation of FRP in case of crown fires was evaluated. The results will be presented as polygonal coverage for GIS.

Thus, remotely obtained FRP data are the basis for estimating the wildfire type, classifying post-fire damages, calculating burned biomass, as well as forecasting the recovery process. The approach could be used for the quantitative and qualitative monitoring of wildfire emissions as well as for assessing the global carbon budget.

The study was supported by the Russian Science Foundation (#14-24-00112).

B1.5

Relationship between tree growth and leaf $\delta^{15}N$ values of black spruce grown in different slope positions in Interior Alaska

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Nitrogen is one of the most limiting nutrients of plant growth in Interior Alaska. The stable nitrogen isotope ratio ($\delta^{15}N$) of foliage reflects patterns of soil-plant nitrogen uptake. We analyzed foliage $\delta^{15}N$ of black spruce (*Picea mariana*) grown in different positions on a northeast-facing slope, in which tree size significantly differed. We set a line transect plot of 1.6 km in length along the northeast-facing slope in the Caribou Poker Creek Research Watershed (CPCRW). Foliage $\delta^{15}N$ values varied between -2.9 to -13.1‰ and positively correlated with tree growth rate. Tree growth rate was strongly affected by altitude and direction of slope; the growth rate at lower altitude (e.g., 250 m) with a shallow active layer during the growing season was lower than at higher altitude (e.g., 350 m) with a deeper active layer, and was also limited on the northeast-facing slope. These results indicated that nitrogen utilization of black spruce significantly varied with slope position, and growth of black spruce on the north-facing slope or the lower position may be restricted by low nitrogen availability. We also measured $\delta^{15}N$ value and nitrogen content of fine roots; these results will be discussed in the poster.

B1.6

A postmortem approach to quantify effects of natural and anthropogenic disturbances on long-term forest development under climate change

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Quantitative understanding of forest development under changing climate is important in sustainable management of forest ecosystems. Forest development is in turn affected by natural and anthropogenic disturbances of various kinds. However, the effect of such disturbances on forest development is not easy to evaluate quantitatively if the background climate is changing. Here we present a postmortem approach to estimate structural stand development quantitatively by using a stand reconstruction technique. This approach can be applied to evaluate the effects of various disturbances in the past (both natural and anthropogenic) on quantitative stand development if tree ring and stem size information on larger dead stems are analyzed with those of living stems simultaneously. The approach is a hybrid method between two stand reconstruction techniques developed by Osawa et al. and Metsuaranta et al. during the last decade, and allows estimation of stand structure changes under the effect of various disturbances. An approach to extrapolate current forest growth to estimate stand-level biomass in the future is also described. The method is applied to reconstruct structural development of a pine stand at Hyytiala, Finland, a black spruce stand at Fort Smith, Canada, and Japanese Cedar stands at Gifu, Japan in order to illustrate its potential.

B2.1

Managing stratified mixtures of silver birch and Norway spruce

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Boreal forests in Scandinavia have been managed according to models of homogeneous monospecific plantations for the last seven decades. However, forests are often more mixed and heterogeneous than these models prescribe. Increased focus on other management objectives than industrial wood production calls for a more systematic use of species mixtures and heterogeneous stand structures. Planting Norway spruce on clearcuts is a common practice and mostly results in abundant natural regeneration of pioneer species like silver birch. The fast growth of silver birch supplements the slow growth of Norway spruce in early stand development, resulting in increased yield in these temporary stratified mixtures. Instead of cutting birch to waste in pre-commercial thinnings, birch could be harvested in early thinnings and used for bioenergy. Managing temporary stratified mixtures is more intensive than the current management of pure stands and requires new decision support tools. Individual tree-based growth models will help to choose a density and time of removal for the birch shelter that suits given management objectives. We collected data in stratified mixtures of silver birch and Norway spruce in Norway to test Swedish growth models for these young stands. Results of model tests will be presented and silvicultural decision support tools for Norway recommended.

B2.2

New procedure for modelling the belowground biomass distribution and resource acquisition in mixed uneven-aged stands

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A new spatially explicit and multi-layered discrete model describes the spatial distribution of belowground biomass and allows simulation of competition between trees for soil nutrients. The tree-specific area of nutrient acquisition is calculated from the average and maximum root spreading distance based on stem diameter. Inside the potential area, a preferability of the occupation is calculated for each cell based on the amount of available nitrogen in the current cell, distance to the stem base and the mass of roots of other plants. The vertical distribution of biomass of roots in mineral soil is calculated as an exponential function of depth with species-specific coefficients. The model was parameterized and verified with field data. The results of the simulation showed that bringing more complexity into the structure of the stand (including initial spatial location of trees, species composition and age structure, vertical structure of canopy) resulted in higher spatial variation in competition intensity. The effect of the spatial location of trees on root distribution and nutrient uptake can be modelled with relatively simple algorithms that apply also in the mixed stands with several competing tree species and multiple canopy layers. This indicates that stands with complex canopy structure had high plasticity in their root systems and were adapted to intensive competition for soil resources. The model will be further incorporated into an ecosystem model to refine the description of belowground competition in mixed uneven-aged forest stands. The work was supported by the Russian Foundation for Basic Research, grant number 15-04-05400, and the Academy of Finland, project numbers 140766 and 278151.

B2.3

Consequences of continuous cover forest management systems in Sweden

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Continuous cover forest management is considered useful in delivering valuable forest ecosystem services such as species diversity and recreation values. In Sweden, clear-felling followed by planting or natural regeneration has been the totally dominant management system for more than 50 years, resulting in single-layered tree stands of different ages dominating the landscape. Increased use of continuous cover systems is today promoted by the forest agency as a tool to obtain more diversified forest management. To support decisions about where, how and why continuous cover systems can be applied, we analysed consequences of four different management options for a range of typical stands. The four alternatives were: single tree selection in multi-layered Norway spruce, conversion of single-layer Norway spruce to a multi-layered stand structure, gap cutting in Scots pine and shelterwood in Scots pine. Stand development, timber production, economy, carbon sequestration and structures for biodiversity were simulated with the Heureka software. The results indicate that the continuous cover systems have a long-term net timber production that is 60 – 90%, and net present values in the range of 60 – 100%, as compared to clear-felling and planting alternatives. Effects on other ecosystem services and especially species diversity are discussed and can be expected to be enhanced by the continuous cover systems.

B2.4

Short-rotation forestry (SRF) with silver birch (*Betula pendula* Roth) on previous agricultural lands in hemiboreal Estonia: Productivity and plant-soil relations during the first half of the rotation period

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SRF is a novel silvicultural approach in Estonia to satisfy the increasing demand for industrial wood and to protect natural forests. Silver birch (*Betula pendula* Roth) as a native tree species is regarded suitable for SRF practise in hemiboreal conditions on previous agricultural soils. The first silver birch SRF plantations were established in Estonia in 1999 on former arable land as experimental and demonstration areas. Productivity and plant-soil relations in silver birch plantations on previous agricultural soils have more often been studied at a young age (<10 years) while studies covering the latter stages of the rotation period are rare. We used repeated monitoring of soil and tree growth in 15-year-old SRF silver birch plantations across Estonia to evaluate: i) growth rate and productivity, ii) impact of soil physico-chemical properties on tree growth and iii) changes in the topsoil chemistry. Growth and yield of silver birch SRF plantations exceeded yield table values of traditional fertile-site birch forest by about two-fold. The most decisive factor for silver birch plantations' growth rate was available water content in the upper soil layer. Concentrations of the topsoil total N and available P had remained at the same level, while available K and pHKCl had decreased significantly compared to the initial status. The concentrations of macronutrients did not limit the growth rate of the birches and fertilization is not needed. To conclude, silver birch has proved to be a suitable tree species for SRF practice based on experience from the first half of the commercial rotation period.

B2.5

Seedling and tree growth after chequered-gap-shelterwood-cutting, and in a conventional clearcut system

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To achieve sustainability both ecological and production aspects need to be considered in forest management. A chequered-gap-shelterwood-system (CGSS) consists of small clearfelled gaps with alternating areas of trees, giving the forest a chessboard appearance which potentially could combine the advantages from both the clearcut system and continuous cover forestry. This approach will introduce more edges which might influence the effect of wind, temperature, and solar radiation on seedlings and trees. In this study, we evaluate the influence of 1) the forest edge and 2) the north- and south-facing parts in the gaps on the growth of seedlings and trees (Pinus sylvestris and Picea abies) in gaps and shelter forests, respectively, and compare the growth with that in a conventional clearcut system.

Overall, edges affected seedling growth negatively and tree growth positively. Seedlings also grew better at the northern sun exposed parts compared to the southern shaded parts of the gaps. As a consequence of these edge effects, seedlings had lower, and shelter trees higher, growth in the CGS system compared to the reference areas. Seedlings in the central part of the gaps grew better than seedlings in the reference area. Norwegian spruce seems to be the most suited tree species for this silvicultural approach. Given the contrasting effect of edges on seedlings and trees, the production over the whole rotation needs to be evaluated in future studies.

B2.6

Shelterwood and continuous forest cover management in Estonia

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In the hemiboreal and boreal forest zones, clearcutting systems have traditionally been used in forest management. A large amount of forest area in Estonia is protected and there is growing public discontent regarding clearcutting. It is hypothesized that different shelterwood systems are a promising alternative to clearcuttings in protected and sensitive areas. Right now, only a small part (3 – 9%) of final fellings is done by using shelterwood systems.

More than 100 shelterwood cutting and continuous forest cover research and demonstration areas have recently been established in Estonia. Research and monitoring focuses on natural regeneration of different tree species, diversity and dynamics of understorey vegetation (vascular plants, bryophytes, lichens), and the impact of root and light competition on the emergence and development of new trees under the shelter of the old forest generation. Also, the shelterwood systems' comparison study area was created in 2012 – 2013 to investigate three different shelterwood systems (shelterwood strip felling, shelterwood uniform system and group selection) in a Scots pine stand using different regeneration types (planting, sowing and natural regeneration). In addition, the effects of soil scarification and NPK fertilization are studied.

On the basis of preliminary results it seems that, in order for shelterwood systems to be more effective, it should be possible to use wider strips, larger groups and lower stem density accordingly in each system. The success of regeneration under the shelter of remaining trees is more dependent on root than light competition in boreal and hemiboreal areas.

B2.7

Transition to sustainable forest management in Russia: Challenges and risks

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Russia adopted national criteria and indicators of sustainable forest management (SFM) in 1998. Analysis of dynamics of the SFM indicators for two recent decades shows that Russian forests are not managed in any sustainable way. The governance of forests has been decreasing substantially. Diverse processes of forest impoverishment are observed in many regions. The infrastructure of the forest sector is weak, consequently only about one-third of the Annual Allowable Cut is used and most of the wood exported is unprocessed. According to IPCC projections, the most dramatic climate change globally is expected in the forest zone of Russia. If the global development would follow the IPCC extreme scenarios (e.g., RCP8.5), warming in the major part of the country by the end of this century is expected to be in the range of 7 – 11˚C. Thawing of permafrost would lead to dangerous changes in the hydrological regime over huge areas and an explosive increase in the extent and severity of disturbances. Russian forests may become a tipping element that would cause their death over huge areas. Under such conditions, SFM means implementation of adaptive forestry. The presentation considers major prerequisites of transition to SFM in Russia: improvements of forest legislation and management regulations; development of a new system of forest inventory; introduction of landscape-ecosystem-based forest management; needs of the minimum standards of adaptation including development of a new system of forest fire protection and preparation of forest landscapes to new climates; necessity of risk estimation within and outside the country's forest sector.

B3.1

Effect of reindeer grazing and forestry on the quantities of ground lichens and Scots pine and deciduous tree seedlings in dry and sub-dry sites in Finnish Lapland

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Reindeer herding and forestry are practiced in the same areas in northern Fennoscandia. We quantified the effects of reindeer grazing and forestry on the amount of ground lichens and pine and deciduous tree seedlings. We inventoried all larger enclosures (49) in Finnish Lapland where forest management practices were similar on both sides of the fence. We estimated the response variables as well as the forest stand characteristics. Grazing considerably affected lichen cover and dry biomass. In the ungrazed (fenced) sites, the average lichen cover (36%) was 5-fold and the biomass (1930 kg ha^{-1}) 15-fold compared with the corresponding estimates in the grazed sites (7% and 130 kg ha^{-1}). In the grazed stands, the cover and biomass of lichens were higher in the mature stands compared to the younger stand development classes, whereas in the ungrazed stands there were no significant differences between the development classes. The influence of reindeer grazing on lichen cover and biomass was much heavier than that of forestry. The decrease of the lichen cover may hinder the recovery of reindeer pastures. Grazing also reduced the number of Scots pine seedlings. Furthermore, the probability of the existence of deciduous tree seedlings was considerably decreased by grazing.

B3.2

A model of population dynamics of dwarf shrubs

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Dwarf shrubs are a functionally important component in boreal forests and their dominance in the understory vegetation is quickly extending northwards to new territories. However, they are not incorporated into any detailed model of forest ecosystems except DGVM, where they are joined into one functional type of understorey vegetation. Such models have yet to be developed due to their complex architectural structure and difficulties in combining existing experimental data into one scheme with the spatial structure of clone patches.

The aims of this study are: (1) to formulate a two-dimensional lattice computer model of dwarf shrubs in terms of generalized discrete description of plant ontogenesis; (2) to determine the main assumptions of population growth of dwarf shrub modules in discrete terms; (3) to demonstrate the model applications for evaluation of the dynamics of populations and communities of dwarf shrubs in changing conditions.

The developed model consists of the computer interactive designer of plant life forms and the model of the population dynamics of dwarf shrubs. The model analyzes the conditions of self-maintenance of a population taking into account the parameters of seed and vegetative reproduction and intra-species competition. The plant consists of aboveground parts: vertical and horizontal shoots, and belowground parts: rhizomes and fine roots. The population dynamics of bilberry, *Vaccinium myrtillus*, has been simulated as an example of analysis of restoration after disturbances and invasion dynamics of dwarf shrubs.

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B3.3

Nurturing bilberry pollination in north boreal forest

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The boreal forest berry plant, bilberry (*Vaccinium myrtillus*) depends on insect pollination. Due to changes in Finnish forests, pollinator habitats have diminished. Especially dead wood offering nesting resources for solitary bees have almost disappeared from managed forests. This has left ground-nesting bumble bees (*Bombus*) almost solely responsible for bilberry pollination, which increases the uncertainty of bilberry harvests. However, ecosystem services like pollination can be nurtured. Honey bee colonies are widely used as a transportable pollination service in agriculture and artificial nests improve conditions of intrinsic pollinator insects, especially solitary bees.

We set up honey bee colonies and artificial solitary bee nests in northern boreal forest in order to improve bilberry pollination. Honey bee colonies were carniolan bees (*Apis mellifera carnica*) in ordinary Langstroth-type hives. Artificial solitary bee hives were composed of aspen planks and polyurethane insulator, in which holes were drilled. These holes were used by the solitary bee females as a nesting resource.

Bilberry fruit sets (percentage of pollinated flowers) near the honeybee hives and artificial solitary bee nests were determined. The results indicated higher pollination success and fruit set up to 500 m and 200 m from the honey bee colonies and artificial solitary bee nests, respectively.

B3.4

Towards optimizing riparian buffer zones: Ecological and biogeochemical implications for forest management

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Undisturbed riparian forests (RFs) along streams and rivers in boreal landscapes sustain many ecosystem functions that are important for biodiversity and biogeochemistry of riparian and aquatic ecosystems. Many of these ecological and biogeochemical functions are maximized in riparian areas with discharge of upland-originating groundwater (GW). Those areas thus represent important hotspots in riverine landscapes. The natural functioning of RFs is threatened by catchment management practices, with forestry being one of the most obvious examples in timber producing regions. Logging operations in riparian as well as adjoining upland forests alter many riparian functions and we have shown that such threats are accelerated in GW discharge hotspots due to their sensitive soils and close hydrological links to uplands. Therefore, we argued that forestry practices should be changed to increase protection of riparian GW discharge hotspots by designing riparian buffers of variable widths, spared from timber harvest. We suggested site-specific riparian buffer management, which incorporates hydrological and thus ecological and biochemical conditions of RFs. We offered a practical tool for such optimized site-specific riparian buffer design in the form of model-derived high resolution wetness and soil-water flow path maps. We concluded that site-specific riparian management, allowing wider buffers at GW discharge areas and more narrow buffers on sites of lower ecological significance (i.e., riparian sites without GW discharge), would benefit a variety of ecosystem services, mitigate negative effects caused by forestry and create more variable and heterogeneous riparian corridors, a feature currently missing in boreal landscapes where fixed-width buffers are prevailing.

B3.5

Reanalysis of live biomass of Russian forests

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Live biomass (LB) is an essential indicator of terrestrial vegetation and carbon cycle. Russian forests cover 23% of the entire world's forest area and two-thirds of boreal forests. We estimated LB based on the Land Information System of Russia (Shvidenko et al., 2010), which consists of hybrid land cover (Schepaschenko et al., 2011) and attributive database. LB of forests has been defined by a regionally distributed multi-dimensional set of regressions, which connect 6 fractions of live biomass (i.e., stem, branches, foliage, stump and roots, understorey, and green forest floor) with biometric indicators of stands (Shvidenko et al. 2007). In total, 9600 sample plots or empirical aggregations (Schepaschenko et al., 2005; Usoltsev, 2011) were used to develop the above models.

The total LB pool of Russian forests was estimated at 36.0 Pg C or 4.7 kg C m^{-2}. The European part accumulates 9.3 Pg C (or 5.7 kg C m^{-2}) and Asian one 26.7 Pg C (4.5 kg C m^{-2}). Stems comprise 21.3 Pg C, branches 3.6, foliage 1.3, roots 7.4, understory 0.7 and green forest floor 1.9 Pg C. Coniferous species accumulate 25.2 Pg C, primarily larch 10.3 Pg C (or 4.2 kg C m^{-2}), pine 6.0 Pg C (4.8 kg C m^{-2}) and spruce 5.0 Pg C (5.9 kg C m^{-2}). Uncertainties of the total LB of the country's forests are within the limits of ± 5% (CI 0.9). We present a set of the equations and LB map of Russian forests at a spatial resolution of 230 m.

B3.6

CO_2, CH_4 and N_2O fluxes in an upland black spruce forest soil in Interior Alaska

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Generally, forest soils act as sources of CO_2 and N_2O, and a sink of CH_4. The objective of this study is to elucidate the changes of these gas dynamics on a slope in an upland black spruce forest in Interior Alaska. The study was conducted near Fairbanks in Interior Alaska (65°N, 147°W). Three plots were established in a black spruce stand (*Picea mariana*) on the upper (U), middle (M), and lower parts (L) of the same slope. The biomass of black spruce, depth of organic soil layer and composition of moss and lichen species were different among the plots. Soil CO_2, CH_4, and N_2O fluxes were measured by using a closed chamber technique with soil temperature and moisture. The differences in soil temperature and moisture among the plots were not clear. The CO_2 flux at L was higher than that at U, maybe due to high accumulation of organic matter. On the other hand, the CH_4 uptake and N_2O flux were relatively higher at U than at L. This higher N_2O flux at U may be due to a higher N mineralization rate. The CO_2 flux at each plot was positively correlated with soil temperature; on the other hand, the CH_4 uptake was negatively correlated with soil moisture. The results suggest that these gas fluxes were different among the plots due to the depth of the organic soil layer and N status, and the difference in each plot was due to soil temperature and moisture.

B6.1

Sighting the future of forests: Science to sight the future of forests – an introduction to the session

Annika Nordin

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The Future Forests programme leads the interdisciplinary scientific development of forest governance and management, supporting the sustainable delivery of forest ecosystem services in Sweden. The programme's future studies aim to postulate possible, probable and preferable forest futures. In this session, we will present results from some of our different approaches to studying the future involving researchers from the Swedish University of Agricultural Sciences, Umeå University, the Swedish Defence Research Agency, Luke and IIASA.

B6.2

Global harvesting of wood under different socio-economic and climate mitigation scenarios

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Climate change and current trends in the world's population, economic growth and other socio-economic issues are expected to further increase the pressure on forests. Mitigation of climate change calls for increased use of wood resources for energy purposes, providing new opportunities and challenges for the traditional forest sector. Increasing world population, rapid economic growth in the developing countries, and changes in the consumption patterns of harvested wood products (HWP) accentuate the changes in the demand for material provision and production of these goods. Using the Global Biosphere Management Model (GLOBIOM), we analyze future development of the forest sector across two interconnected pathways: climate change mitigation efforts and socio-economic developments. The implications of these two pathways are shown in terms of their impacts on harvesting of wood and demand for HWP. We find that stringent climate change mitigation targets have only a slight effect on the use of industrial roundwood for material production. Instead, the results highlight that the harvests of industrial roundwood for material purposes are strongly affected by the anticipated socio-economic development, mainly as a result of changing consumption patterns. On the contrary, for total roundwood harvests and woody biomass use for energy, climate change mitigation targets are found to have a stronger impact than socio-economic development, relating back to the anticipated rapid development of the bioenergy sector. In conclusion, the study stresses the importance of widening the discussion on climate change impacts also into accounting for socio-economic issues when deciding on forest-related policies for the future.

B6.3

Impacts of global climate scenarios on forest management and harvesting in Sweden

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In a globalized world affected by climate change, natural resource management needs to be adapted to meet the uncertainty of future demand. A set of shared socioeconomic pathways (SSP) and representative concentration pathways (RCP) have been developed for the 5th IPCC report as a framework for systems analysis of global effects of climate change and policy implications. The SSP and RCP scenarios can be used as a basis for analyzing impacts across different land use sectors, such as forestry, agriculture and energy. The aim of this study is to analyze impacts of future global demand for wood products and bioenergy on forest management and harvesting in Sweden. Traditionally, the national forest impact analysis in Sweden has been focused on supply potential with little reference to international market development or demand for forest products. To consider changes in consumer demand, production capacity and trade patterns, the Swedish forest sector needs to be analyzed within an international context. In this study, the GLOBIOM-MESSAGE modeling framework provided information on demand for forest products from Sweden, taking competition between geographical regions and different land use sectors into account. The range of demand for forest products over the various SSP and RCP scenarios was expressed as harvest level targets for Sweden and used as input in the Heureka RegWise simulator. The results will display possible contrasts in the global demand on forest products that may be placed on Sweden in the future, and open up a discussion on alternative pathways for Sweden's future forestry strategy.

B6.4

Understanding consistencies and gaps between desired states of the future forest – an analysis of visions from stakeholder groups in Sweden

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The existence of a variety of partially conflicting perspectives or ”frames” in discussions on forests has for a long time influenced the Swedish forest sector and forest policy development in Sweden. The variety of frames, however, constitutes a challenge for policy development. Disagreements about forest futures do not only create conflicts but also deadlocks when the actors are talking past each other. The purpose of this study is to move beyond this situation and apply a more long-term and integrative tool, participatory backcasting, to identify desirable forest futures. By comparing images of the future forest sector among stakeholder groups, our aim is to highlight contemporary trajectories and to identify what changes are conceived as desirable. We identified four groups of stakeholders: the Conservation group, The Forest and bioenergy group, the indigenous Sami livelihood group and the Rural development and recreational group. In total 40 organisations were invited to a series of workshops, two for each stakeholder group, aimed at creating the groups' visions and to sketch events, including policy measures, necessary to reach the visions. Our results show that based on the variety of frames and how the stakeholder groups interpret and seek to change forest policy and practice – now and in the future – it is possible to identify tensions but also synergies between desired futures. We identified well-known but also relatively unknown or new frames related in particular to the forest's social values. It was also possible to identify different coalitions of stakeholder groups with similar values and desired futures, but also groups with completely different visions. Hence, these future images could be used to raise general awareness of tensions between different frames, but also to identify consistencies that could provide bases for compromises.

B6.5

Future forests in Sweden – visions of young people

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Our study focuses on what young Swedish people want from the future forests. We developed an on-line mind-map tool to investigate the preferred forest futures of Swedish university students, who will be future forest users and decision-makers. Forests and forestry are very important in Sweden. Sixty-nine percent of the total land area is forested, and the forest sector accounts for 2.2% of the gross national product. Sweden is a large player in the global forest products market, and for example produces 6% of global pulp for paper. Special features of the Swedish forest sector include the large share of ownership by non-industrial private forest owners (50%), and the Right of Public Access, which allows people to freely enter forests and partake in recreation. These features mean that lots of people have a personal interest in forests and opportunities to visit them. The mind-map was designed to inspire the respondents to formulate their preferences regarding products from the forest, activities related to the forest and the features of the forest, i.e., how they would like the forest to be.

The data was collected in Umeå, Sweden at Umeå University and the Swedish University of Agricultural Sciences in December 2014. The data consists of about 1000 responses from students. The average age of respondents was 23 years, and the gender distribution was about equal. Seven percent of respondents studied forestry, 37% other natural sciences, and 54% social sciences or arts. The respondents came from both urban and rural backgrounds, and were able to correctly identify forests from a selection of photographs. The greatest number of them visited forest monthly and spent 30 – 60 minutes there per visit, but many made more frequent visits.

There were about 2200 different variables mentioned in the mind maps, and about 3400 connections between these. On average, an answer had 15 variables. The data will be analysed for example with network analysis tools. Our aim is to reveal what issues about forests are the most important to the respondents and to analyse how these are related to each other. Our study is an example of a participatory research approach engaging young people in questions and problem areas concerning the future of forests. The results will expose young Swedes' attitudes towards forests and may thus contribute to guiding today's policy-makers in decisions on forest management.

B7.1

The complexity of gross primary productivity in European forests

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Gross primary productivity (GPP) is a key variable in terrestrial ecosystems, and forests in particular, quantifying carbon allocation and biomass growth of vegetation. Changes in GPP can be induced by land use change, environmental disasters or extreme events, and changing climate. Numerous attempts to quantify GPP on larger spatial scales exist. Here, we investigate gridded time series at daily resolution for the European continent either based on measurements from flux towers (”observations”) or modelled with two different process-based terrestrial ecosystem models (”simulations”). We use complexity analysis based on ordinal pattern statistics. This innovative method determines one measure for the information content of time series (Shannon entropy) and two complexity measures, one based on global properties of the order pattern distribution (Jensen-Shannon complexity) and one based on local (derivative) properties (Fisher information or complexity). Results are either visualized as maps of Europe showing ”hotspots” of complexity for GPP, or used to provide a detailed observations-simulations comparison. The spatial patterns emerging can be used for a classification of European (forest) ecosystems according to their complexity; each time series gets classified via its location in an entropy-complexity plane. This classification is compared with existing landscape classifications based on other properties of the terrestrial biota or on climate. The method draws a qualitative distinction between different types of natural processes.

B7.2

Extrapolating stem taper to estimate tree height using single-scan TLS and harvester data

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Tree height is a crucial measure in forest inventories for estimating timber volume or the assessment of site quality. Today, tree height is usually measured using hypsometers, which is a time-consuming and thus costly task. Terrestrial laser scanning (TLS) has developed rapidly over recent years and several tree parameters of interest in forest inventories (e.g., dbh) can be assessed with promising accuracy from single scans. However, due to occlusion by branches and leaves, measuring tree heights directly from single scans is usually impossible.

Single-scan TLS data from 965 spruce trees were acquired using a tripod-mounted FARO LS 880 scanner. The TLS data covered most frequently less than 50% of the stem height. Tree heights were measured independently using traditional methods. The measured trees were cut afterwards resulting in harvester-measured stem diameters.

We fitted flexible tree taper curves to diameter-height measurements from TLS. Single tree height was estimated by minimisation of the differences between diameters measured by TLS and diameters estimated using taper curves. The same methodology was applied to harvester data for comparison.

The coverage of the stem with measurements has a strong influence on the accuracy of the tree height estimates. In general, if TLS measurements sufficiently represent the stem taper, the accuracy of the tree height estimates improves. The taper equations used provide a good means to extrapolate (and interpolate) TLS and harvester measurements.

B7.3

Inference in unit- and area-level small area estimation

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The availability of valuable 3D remote sensing data, such as airborne or spaceborne laser or image matching data, increases constantly. Especially in regions with limited ground access, remote sensing data entrap into making estimates on forest parameters that are based on no or limited numbers of field observations. While means or totals of the variable of interest are often estimated today, uncertainties in the form of variance estimates are often not provided.

From a sampling perspective, the applied estimators can be categorized as model-based small area estimation (SAE) methods. SAE methods require (field) observations for model calibration but not necessarily for estimation, and also allow variance estimates.

SAE methods can generally be classified as unit-level or area-level approaches. In the unit-level approach, field data need to be exactly co-registered with the remote sensing data in order to derive a regression model. The regression model is used to map the response variable of interest, such as biomass or timber volume. The mean of the estimated map pixels within a certain area is known as the synthetic estimate.

In the area-level approach, estimates of the response variable need to be available for some domains in order to derive a regression model on the domain level. Exact coordinates of the sample plots are not required.

Model-based variance estimators are defined for both the unit- and area-level approaches. Advantages and disadvantages of the two approaches are discussed based on example data.

B8.1

Biodiversity gains without the mortality pains: Improved regeneration as a pathway to achieving win-win outcomes in production forests

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A substantial proportion of biodiversity value in Sweden's production forests arises from natural broadleaf regeneration taking place where planted conifer seedlings have died. Mortality among conifer seedlings may be caused by pre-planting seedling stress, planting procedures, insect and ungulate browsing pressure, pathogens, climatic stress and site conditions. The spatial grain of mortality may take place i) within patches of distinct site conditions, or ii) interspersed throughout the stand at the scale of the individual seedling. Advances in regeneration sciences are now increasing seedling survival to the extent that the continued benefits to biodiversity derived from past regeneration failures are now in question. Here we examine the current contribution of these failures to stand-level biodiversity, and determine the extent to which the unintended resultant benefits to biodiversity may decrease in the future. Using five alternative intensities and pathways for conifer stand establishment and regeneration, we model how win-win outcomes for production and biodiversity can be better planned for and maintained over coming centuries, and provide a framework for achieving these goals.

B8.2

Insect pests in future forests: Utilizing complex interactions to mitigate damage

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It is commonly anticipated that insect pests will cause more damage in future forests, mainly because insects respond positively to increased temperatures. Two facts might alter this simple prediction. First, it is not only the insect pests but also their host trees and their natural enemies that respond to warming temperatures. Second, other environmental drivers also affect insect pests, e.g., nitrogen deposition and land use. All of these factors may be connected, making it difficult to make simple predictions. At the same time the interactions between these factors can, when the mechanisms are understood, be used to mitigate unwanted effects of climate change. Here we present results from two systems–pine sawflies and willow leaf beetles–in which we have started to acquire knowledge about these complex interactions, thus making it possible to formulate possible ways to reduce climate change effects. For example, our results imply that the risk for pine sawfly outbreaks will increase in a warmer climate but only on pines with low levels of diterpenoids. As diterpenoid content is largely genetically determined, it would be possible to select tree genotypes with traits that reduce the risk for sawfly outbreaks. Another example is our finding that nitrogen levels in willows affect the predation by predatory bugs on damaging leaf beetles. Since the predation rate is also affected by willow genotype, it would be possible to reduce the risk for insect damage by selecting certain willow genotypes and providing certain levels of nitrogen.

B8.3

Modeling and prediction of forest insect population dynamics

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Forest insects are one of basic factors of impact and death of boreal forests. A set of models was proposed for describing insect population dynamics and pest outbreak risks. These models include ARMA models used for short-term forecasting of population density; second-order phase transitions models for linking the population density and relative abundance of insect population; first-order phase transition model describing the impact of environmental factors on outbreak development; and, model of food consumption by insect for estimation of the individuals' fertility. The proposed model allows the estimation of the risk of outbreaks by species – the objects of entomological monitoring in relation to tree health and weather conditions. The proposed model allows assessment of the risks of insect invasion into new territory depending on the current density of the population of invaders.

The work was supported by RFBR (grant 15-04-01192).

B8.4

Dark needle conifer decline and mortality in southern Siberia

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The mortality of “dark needle conifers” (DNC: *Pinus sibirica, Abies sibirica* and *Picea obovata*) was documented as widespread in Russia. We analyzed patterns and causes of Siberian pine and fir mortality in southern Siberian mountains. Tree mortality started on shaped hilltops with steep slopes, shifting over time to lower elevations and gentle slopes. Maximum mortality was found within terrain elements with the highest water stress risk [convex steep (15° – 25°) southward slopes]. Dendrochronological data showed that Siberian pine and fir mortality occurred after consecutive droughts. Dendrochronological data showed that decline and mortality were correlated with vapor pressure deficit, drought increase and late frost occurrence. Remotely sensed data showed that tree mortality was accompanied by both decreased soil moisture and GPP. Later on, a consequent GPP increase was attributed to vegetation growth release due to a decrease in upper canopy shading. An impact of previous-year climate conditions on the current ring width was found; that was attributed to the sensitization of drought-induced trees to insects and fungal impact. The results obtained showed a primary role of water stress in Siberian pine and fir mortality with a secondary role of biotic impact. Geographically, DNC mortality was observed within the southern parts of the DNC area. Mortality began on the margins of DNC stands and within forest-steppe and conifer-broadleaf ecotones. Meanwhile, if model projections of increased aridity are correct, DNC within the southern part of the DNC area will be replaced by drought-resistant species (e.g., *Pinus sylvestris* and *Larix sibirica*).

This research was supported by the Russian Science Fund (RNF) grant [No.14-24-00112].

POSTER ABSTRACTS

P1

Effects of open-field artificial warming on growth responses of *Fraxinus rhynchophylla*, *Zelkova serrata*, *Betula costata* and *Quercus variabilis* seedlings

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The objective of this study was to investigate growth responses of seedlings of four major Korean deciduous species (*F. rhynchophylla, Z. serrata, B. costata* and *Q. variabilis*) to open-field artificial warming. The seeds were sown in April 2014 and the newly germinated seedlings were warmed with infrared-heaters to maintain an air temperature 3°C higher than that of control plots. The responses of growth (root collar diameter, shoot length, and root length) and biomass allocation (root weight to total biomass (RMR), root weight to leaf weight (RLR), and root weight to shoot weight (RSR)) to warming measured in June, August, and October 2014 differed between species. In warmed plots, height to diameter ratio (H/D ratio) of *F. rhynchophylla* increased by 28.6% ($p<0.05$) compared to control plots in June, whereas RMR, RLR, and RSR tended to decrease. Shoot length, root length and total biomass of *Z. serrata* increased, while root weight of *B. costata* decreased in warmed plots. In *Q. variabilis*, growth, H/D ratio and total biomass increased, although the differences were not statistically significant. Meanwhile, RSR decreased by 30.2% ($p<0.05$) compared to control plots in October. Growth and biomass of seedlings might increase due to enhanced photosynthesis and extended growing season, while decreased root weight could result from increased stem and branch weight at the expense of roots. Since strength of environmental factors and growth processes vary with the species, drawing a generalized conclusion is difficult. Therefore, continuous species-specific artificial warming experiments are needed to elucidate the causes of responses.

P2

A bibliometric analysis of boreal forest research during 1996 – 2013

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Bibliometrics is a research method used to measure scientific output, level of influence of a researcher or organization, changes in research focus and levels of collaboration between researchers and organizations. This study presents an analysis of research trends and collaborative research activity related to boreal forests from 1996 – 2013 based on journal articles identified within the Scopus database. Several indicators were used to review the temporal evolution of scientific productivity over the specified period, including growth of article output and author productivity as well as spatiotemporal and categorical patterns in boreal forest research. There has been a steady increase in article output since 1996. Canada was the main contributor to boreal forest research followed by the United States, Finland and Sweden. There has been a steady increase in the level of international and national (inter-organizational) collaboration. Additionally, multi-author papers have increased, particularly with respect to 3-, 4-, 5- and 6-author articles. An analysis of author collaboration using a co-authorship index indicates that the proportion of multi-authored (3 or more) articles is much higher for Norway than the average for other boreal countries. Canada and the US had the lowest proportion of multi-authored papers. A keyword analysis showed that climate change, including carbon, has been a central focus of boreal forest research activity. Other key thematic areas include biodiversity, forest management, biomass, ecosystems and remote sensing. The study highlights patterns in boreal forest scientific outputs and collaborations and illustrates an alternative way of revealing research tends in the circumboreal region.

P3

Towards forest-based bioeconomy in Finland and Russia

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Aldo Leapold in his book ”A Sand County Almanac” labels 2 groups A and B. ”Group A regards the land as a soil, group B regards the land as biota”. Group A is observed as an agronomic approach to forestry. He writes, ”Group A is quite content to grow trees like cabbages, with cellulose as the basic forest commodity” while group B considers the land as the whole integrated system. This shows us that, on the one hand, we all understand that forestry is one of the key players in the sector of economy, and on the other hand, forest is a complicated ecosystem mitigating climate change and enhancing biodiversity. The former President of Finland Martti Ahtisaari at FAO, Rome on 22 November 1999 started his speech with the following words: ”These days forests are not only a local and regional issue. They are very much a global issue.”

Nowadays although the political situation in the world is very difficult, we still cannot deny that countries are bound together economically. The bioeconomy could be a good basis to improve these relationships, without harming nature. In my mind, the ecological issues that arise depend on the quality of the legislation. Nowadays both in Finland and in Russia, the activities of bioeconomy are being developed. The aim of this research is to observe how law enables and constrains the development of (forestry-based) bio-economy in Finland and Russia.

P4

How is logging residue harvesting reflected in the soil solution N and C concentrations 6 years after the clear-cut?

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Logging residue harvesting for bioenergy in connection with clear-cutting is a widely used practice in Finland. In logging residue harvesting where needles are also harvested, significant amounts of nutrients (e.g., N) are removed from the forest ecosystem. The aim of this study was to determine how harvesting or leaving logging residues is reflected in the soil solution N and C concentrations 6 years after the clear-cut. Solution retained in the soil matrix was extracted from the soil samples by the centrifugation method. The study site was located in Paltamo, northern Finland, where a Norway spruce stand growing on sandy soil was clear-cut in 2007. Soil solution was extracted from the soil samples of the O, E, B, BC and C horizons of the podzolic soil. Samples were collected in October 2013 from the experimental sample plots which contain the following treatments: 1) no logging residues, 2) 40 kg m^{-2} fresh spruce branches.

The DOC, DON, NH_4-N and NO_3-N concentrations were clearly higher on the experimental sample plot where logging residues were left on the site compared to the situation where they were harvested. The clearest difference in the DON and DOC concentrations between the two treatments were found in the O and E horizons, while the NH_4-N and NO_3-N concentrations were higher in all the soil horizons in the treatment containing logging residues. In conclusion, logging residues are important from the point of view of nutrient concentrations in soil solution several years after the clear-cut.

P5

Changes of the coniferous forest line in Finnish Lapland during 1983 – 2009

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The boreal timber- and tree-line forests grow in harsh conditions in their outermost distribution limit. Already small environmental changes, like higher temperature sums or a prolonged growing season, may cause dramatic changes in the distribution of tree species. We examined changes in the forest lines of Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*) in Finnish Lapland during 1983 – 2009. We monitored the number of stems and the volume of the growing stock on 13 locations in forest line areas. The linear trends and the variations of these response variables were used as indicators of a possible change. Spruce showed a highly significant increase in the volume of the growing stock and in the total stem number. Pine also showed a highly significant increase in the volume of the growing stock but indicated stagnating or decreasing number of stems. Apparently, spruce needs favorable conditions to have an abundant regeneration, but after establishment spruce seedlings seem to be more resistant against biotic and abiotic disturbances than pine. The temperature sum was related to the increase in the stem number of spruce only in western Lapland, whereas pine showed no clear relation to the temperature sum. Our results suggest that responses to environmental changes in the boreal forest line are species-specific and hence more favorable environmental conditions do not necessarily lead to expansion of the coniferous forest line. It is necessary to continue similar observations also in the following years to evaluate the balance between regeneration, climate and disturbances in a changing environment.

P6

International framework for sustainable development: Overview and analysis in the context of forests and forest products

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Ecosystem services offer a wide variety of business opportunities in forests and forest products. Green Business value chains offer opportunities in the context of forests and forest products. The Green Economy covers the concept of Bioeconomy.

Forest policy can enhance sustainable development. Corporations may enhance sustainable development, competitiveness and Corporate Social Responsibility. Legal system, agreements, certification and standards offer a tool in sustainable development.

This is qualitative research based on literature reviews.

P7

Gap cutting results in good Norway spruce natural regeneration in drained spruce mires of northern Finland

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Easy natural regeneration of peatland spruce mires has been known for decades. Due to its high moisture, peat soil is a good substrate for establishment of Norway spruce (*Picea abies* (L.) Karst.) seedlings. In practice, however, most of spruce peatlands are artificially regenerated even though difficulties are encountered due to vigorous ground vegetation, frost damages, and loads to watercourses. Thus, there is a need for alternative methods of natural regeneration in productive spruce peatlands. Two field experiments were set up in mature spruce mire forests in 2005 to monitor natural spruce regeneration in small canopy gaps in northern Finland. Gap diameter varied from 10 m to 25 m. Seedling inventories were carried out for the 5-year post-cutting period. After five years, the average density of established (> 10 cm tall) spruce seedlings was 4500 ha^{-1}. Gap size did not explain the number of established seedlings. The proportion of pubescent birch out of total seedlings was positively correlated with gap size being 7% in the smallest gap and 30% in the largest 25 m gap. In the northern experiment, the number of crop seedlings after 8 years was 1654 ha^{-1} with three gaps still lacking crop seedlings. Height growth analysis showed that after the five-year recovery period, seedling height development was comparable to that observed after release cutting, but clearly less than that observed in spruce plantations. The results suggest that small canopy gaps will regenerate effectively within five years resulting in sufficient crop seedling density with good later height development.

P8

Ecotone: Modeling of the structure, stability and susceptibility to external impact

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An ecotone is a transition zone between two types of plant communities. It represents an ecosystem with a high spatial gradient of biodiversity. To describe the ecotone, the authors proposed a one-dimensional model of ecological second-order phase transition and the macroscopic characteristics of ecotone-order parameters. Based on the proposed model, the authors examine the classification of ecotones and their critical characteristics. When the ecotone reaches the critical characteristic, a qualitative change in its state occurs. In this paper, we examined the processes of ecotone formation andevaluated the factors of its stability, size and biodiversity gradient, depending on the nature of the plant interaction within the ecotone and the influence of external factors. The authors propose a function of the characteristics of ecotone susceptibility to external influences, which are considered as fields in a model of phase transitions. The paper assesses the susceptibility of the characteristics of different ecotone types to external modifying factors (e.g., climate) and examines the use of changes in the ecotone characteristics in environmental monitoring.

The ecotone model is verified using distance and ground data for the taiga forests of Siberia.

The work is supported by RFBR (grant #15-05-02845).

P9

Testing of spruce stand protection with anti-attractants during bark beetle outbreak (2012 – 2014) in Moscow region

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We tested the use of anti-attractant-based spruce stand protection in the Moscow region during the period 2012 – 2014. Experiments in 2012 and 2013 were based on existing technology and methods developed for conditions of Central Europe. We used a point source experimental dispenser, IT Rep (Fytofarm, s.r.o.). The active compounds were verbenone and NHV (non-host volatiles). The results of the experiments were unclear. The main problem was that the experimental methods were developed for homogenous spruce monocultures in Central Europe. In the Moscow region, the spruce forests are heterogeneous. In 2014, we developed a new linear dispenser and changed the experimental design. Preliminary results are promising.

P10

DataPuu – forest experiment data services

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The DataPuu system provides information for research from the big data of forest experiments collected during decades throughout Finland. With the integrated system, forest researchers can retrieve old experimental data, combine it with new data, set novel research questions, and get answers to those quickly.

The Finnish Forest Research Institute (Metla)* conducted an extensive amount of research experiments across Finland over decades. The oldest trials still being monitored were established in the 1800s. The data of the experiments have been previously collected manually and stored in diverse ways. Hence, using the data outside its original research context has really been challenging. However, this kind of long-term monitoring data is highly valuable and could easily be reused if stored in a consistent way.

The DataPuu system was developed in the EU-funded LifeData project to ensure that old monitoring data can be reused with new data and research contexts. The system was designed and implemented as a relational database with a web-based user interface. Functionality to support input of old data and storing of newly measured data automatically were developed. Calculation and simulation programs have been integrated into the system making it a comprehensive system for forest research. The system illustrates basic statistics about the measured and calculated data. It enables data searching and mining, and provides interfaces to other specific analysis systems. The DataPuu service improves the efficiency of the research activities.

** Known as Natural Resources Institute Finland (Luke) since 1.1.2015.*

P11

Value – an online tool to delineate catchments

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The method of using large databases, which were previously used by principally state administration experts, needs to be fluent and easy to adopt for multiple users and complex perspectives. Open data applications give added value to environmental and natural resource datasets in the fields of research and management.

A new internet map application tool (Value) enables the user to delineate catchments for any river segment or lake in the Finnish river network information system. The delineation of a specific catchment is based on the flow direction grid (10 m resolution) and Finnish river network dataset including all the rivers with a catchment area of 10 km^2 or more. The application also offers the user the possibility to calculate the land cover classification statistics of the catchment. The catchments created with the tool can be downloaded as a GIS dataset. The user is also allowed to view datasets published in network services together with the catchments, or even with the user's own GIS data. This versatile tool is thus suitable for various purposes of use.

The tool has been developed in SYKE for the environmental administration in Finland, and it is now shared more widely as part of the LifeData project supported by the EC Environment Life+ financial instrument. Use of the tool is free, and the tool will be available for everyone via SYKE's internet portal.

P12

A novel GIS-based approach for sustainable land use planning

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The increasing awareness of the non-economic benefits of forests, such as biodiversity and recreation, has challenged the land use planning of tourism areas. Sustainable land use planning should ensure conservation of biodiversity and the social acceptability of land management actions as well as the use of natural resources in an economically sustainable way. Thus, authorities need new means to use and benefit from existing ecological information and knowledge of people's values in land use planning. We develop a new GIS-based operations model, which can increase social acceptability and ecological sustainability of land use planning. The project's pilot areas were tourism resorts, which are located close to protected areas. First, we compiled existing spatial ecological information (e.g., endangered species, habitats) on the study area. Secondly, the socio-cultural knowledge with spatial reference related to the study area and values related to different land uses was collected from stakeholders through internet-based PPGIS survey. Then, the ecological and socio-cultural information were combined and we examined how they were distributed on the map. Through spatial data analysis, we located ecologically and socially valuable areas with possibly conflicting land use pressures. Based on the new socio-ecological knowledge, we created a classification system which can be used to rate different areas into different land use classes based on their suitability.

P13

Leaf morphological and physiochemical traits of 40 broadleaf trees in Interior Alaska

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Leaf morphological and physiochemical traits are important to adapt to growth environments because they are central to functions such as photosynthesis and drought tolerance. We investigated the leaf morphology, toughness, leaf mass per area (LMA), and nitrogen content across different life forms of 40 broadleaf tree species in Interior Alaska. All trees were divided into 3 life form types by maximum tree height: understory (< 1 m), small (1 m ≤ height < 5 m), and canopy (5 m ≤) trees. Evergreen species accounted for a relatively large proportion in understory trees (44%), whereas small (13%) and canopy (0%) trees consisted mostly of deciduous trees. Almost twofold larger LMA and leaf toughness in evergreen trees contributed to longer leaf longevity compared with deciduous trees. We also focused on the existence of bundle-sheath extensions (BSEs), which usually accelerate photosynthetic ability by increment of water conductivity and light transmission in the leaf. In total, 11 species (28%) had homobaric leaves (BSEs absent), and 29 species (72%) had heterobaric leaves. This ratio is similar to that for temperate deciduous forests in North America. We also found that the proportion differed clearly across life form types. Most canopy species had heterobaric leaves (89%), whereas heterobaric species decreased in small trees (73%) and understory (63%) species. Our results suggest that tree species in the boreal forest adapt to spatial differences in the environmental conditions by having different leaf types with physiological and/or mechanical functions.

P14

Mixed forests to mitigate climate change effects on insect pests

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Over the past decades, the consequences of the changing climate have become more apparent in observed weather patterns. Damage by insects is thought to be related to weather events like drought and storm. These types of weather events increase, on the one hand, the number of trees with reduced defence and thus their proneness to insect damage. However, on the other hand, there are insect species whose populations are governed more by natural enemies. Such populations often show strongly fluctuating dynamics, irrespective of weather events. The efficiency of natural enemies to control their host populations could be influenced by habitat structure. Therefore, considering management alternatives, i.e., mixed forest, could be a strategy to mitigate insect damage in the future.

P15

Torrefaction as a method for improving the properties of wood fuel

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The pressure to increase the use of renewables in the energy sector has created a need for improved solutions. In Finland, the use of wood can easily be increased, but untreated wood fuels possess many problematic features that affect the profitability of the supply chain. Moisture is the most important quality issue, as it increases the mass of the fuel in transport, causes dry matter losses, oxidation, and microbial contamination in storage, and reduces the energy yield as well as increases the emissions in combustion. To overcome these problems, wood can be pre-treated with mild pyrolysis, or torrefaction. During torrefaction, the feedstock is subjected to thermochemical degradation processes and transformed to a product with increased energy density and brittleness, and reduced hygroscopicity and volatiles.

Torrefied biomass could increase the co-firing ratio in existing coal-fired plants but the logistics of the material still entail some unsolved issues. The advantages obtained in the pre-treatment depend greatly on the hydrophobicity of the material. Though it is hydrophobic, the material is not protected from capillary water, which in turn may bring about problems – as the material gets wet, the savings obtained in transport, storage and combustion are reset. For example, capillary absorption facilitates allergenic fungi and reduces the energy of combustion. Here, different advantages and disadvantages are brought forward and compared. The question whether torrefaction is a promising option for improving the properties of wood fuel is discussed.

P16

Changes in ground vegetation after stem-only and whole-tree harvesting in forests on dry mineral soils in Latvia

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The demand for energy wood in the European Union is believed to increase in the future so as to meet the ambitious EU renewable energy targets. One option to satisfy this demand is increased utilization of forest biomass, including removal of branches, tree tops and stumps during various forest management activities. In Latvia, special emphasis is put on the extraction of logging residues, which has increased substantially during recent years. Even though the effects of whole-tree harvesting on various aspects of the forest environment have been rather extensively investigated, the results are often controversial and knowledge gaps still exist. More information about the effects of intensified biomass removal on water quality and terrestrial biodiversity is needed. Ground vegetation community structure and composition are good bio-indicators of site properties and environmental change, therefore these parameters were used in a research project where the environmental impacts of whole-tree and stem-only harvesting were studied.

The research was carried out in two forests on mineral soils located on slopes: *Myrtillosa* and *Hylocomiosa* site types. Six study plots were established in each site: whole-tree harvesting (WTH), stem-only harvesting (SOH) and control (C) plots on the upper part of the slope and three forest buffer zone plots on the lower part of the slope, respectively. Ground vegetation structure (vascular plants and bryophytes) was measured in summer 2012 prior to clearcutting and in summer 2014 two years after clearcutting. The differences in the development of ground vegetation and environmental conditions following two types of clearcutting are presented and discussed in this poster.

P17

Winter in changing climate: Effects of snow conditions on plants, soil and their interactions in the boreal forest

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The frequency of rain-on-snow events and winter warm spells is increasing in high latitudes and is forecasted to further increase in the future. By decreasing the insulation capacity of the snowpack and causing ice layer formation or ground ice encasement, these events are modifying soil properties and conditions under the snowpack. Ice layers limit the soil-atmosphere gas exchange and continuing soil microbial activity may lead to hypoxia and anoxia, affecting the normally aerobic overwintering conditions of plants and soil microorganisms in boreal ecosystems. Although less frequently studied but most likely as important as changing conditions during the growing season, changing winter conditions are expected to affect productivity and biodiversity of boreal forests.

To investigate this question, a field experiment of snow manipulation (ambient, snow removal, ice encasement and snow compaction) began in autumn 2013 in a boreal forest in the Rovaniemi area. After one winter of the experiment, the results showed that changes in snow conditions led to drastic changes in soil gas concentrations (CO_2 accumulation in relation to development of hypoxia), decreased Scots pine and Norway spruce seedlings' winter survival and growth in the following summer (species-specific responses), and modulated nutrient content and enzymatic processes in the soil. Results from the ongoing analysis of C and N pools in seedlings and composition of soil microbial communities will also be presented. After one winter of snow manipulation, our data suggests a negative impact of changing snow conditions on the boreal forest ecosystem, which could counteract the positive effects of climate warming.

P18

Carbon storage in black spruce stands on north-facing slope in Caribou Poker Creek, Interior Alaska

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Black spruce (*Picea mariana*) stands develop after large fire disturbance in Interior Alaska. The dominant landscape of north-facing slope, where mature black spruce stands develop, is accompanied by underlying permafrost. We selected a ca. 1.5-kilometer long toposequence along the northeast-facing broad ridge topography in the Caribou Poker Creek Research Watershed, CPCRW. We examined the relationship between active layer depth during the growing period and forest biomass regime among the stands. Deeper active layer depth was detected in the upper position of the slope. The shallowest active layer depth was recorded at the lower slope position of the north-facing slope. The forest floor in all stands was covered with a thick moss-lichen layer, ranging from 20 to 35 cm in thickness. Larger aboveground biomass C accumulation occurred in the upper position of the slope. The smallest value of C accumulation in plant biomass was 4.5 Mg C ha^{-1}. We also selected two contrasting stands along the north-facing slope, which showed high and low levels of stand biomass accumulation. Patterns of forest stand development along the slope were reconstructed based on tree ring analysis.

P19

Impacts of harvesting practice on base cation budgets of coniferous stands in Finland – a sustainability study

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We simulated the impacts of final felling harvestings on base cation (Ca^{2+}, K^{+} and Mg^{2+}) budgets in boreal forests under the scenarios of stem-only harvesting (SOH), whole-tree harvesting (WTH) and WTH + stump and root harvesting (WTSR). The study included five Scots pine and five Norway spruce stands belonging to the UN-ECE ICP Forests Level II programme in Finland. A mass balance approach was used: base cations (BC) in total deposition (TD), weathering (W), leaching (L), and harvesting removals (H) fluxes were estimated and analysed for the effect of tree species and climate (latitude). Soil stocks of exchangeable BC were measured and BC exports in the final fellings were estimated. A sustainability index (SI) for the hypothetical harvesting impacts on soil BC sustainability was calculated as: TD + W - L - H.

TD of BC on spruce plots correlated negatively with latitude, and was significantly higher than that for the pine plots. BC amounts in the final fellings of all scenarios were larger for spruce than for pine. In most stands, harvesting removals of BC were significantly higher in WTH than in SOH. BC removals in WTH and in WTSR did not differ significantly from each other. Harvesting intensity negatively impacted the sustainability of BC. WTH had a more negative impact on soil BC stocks in the spruce than pine stands. The SI for pine K, spruce K, and spruce Ca were, on average, negative under WTH and WTSR, and SI for Mg were, on average, positive in all harvesting scenarios.

P20

Simulating the effect of fire regimes and projected temperature scenarios on Canadian boreal forest carbon storage

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The boreal forest is experiencing unprecedented changes in climatic conditions. At regional scale, these changes are expected to affect carbon dynamics through modifications in the historical fire regime, soil decomposition, among others. The objectives of this study were to investigate how boreal ecosystem carbon stocks and fluxes respond to variation in fire regime and to quantify the effect of projected temperatures on the carbon balance for the black spruce domain of northern Quebec, Canada. A size-class structured demographic model coupled with a standard matrix model of biomass and soil carbon was developed to simulate carbon dynamics. Fire regime was characterized by observed fire return intervals (FRI) (1200, 700, 300, 150, and 60 years) within the domain. Three IPCC temperature scenarios (RCP 2.6, 4.5, 8.5) simulated by HadGEM2 for the period 2011 – 2040 were used as inputs to simulate decomposition of the soil C pools. Simulated black spruce stands were sampled from a pool of inventory plots. Ecosystem carbon stocks and fluxes were estimated after 500 years and averaged over 1000 replicates. Relative influence of the predictor variables was determined by ANOVAs. Our results indicate a strong effect of FRI on boreal C stocks and fluxes. Model simulations demonstrate that under RCP 8.5, the total ecosystem C stock was significantly reduced by 8% compared to current stock estimates. Fluxes did not differ among scenarios. Simulations using long-term temperature predictions are recommended. Overall, decreasing FRI resulted in negative NEP, shifting the boreal forest from acting as a relatively low sink to a net carbon source.

P21

Decaying wood harbors high fungal diversity in boreal forests

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In boreal forests, fungi have a pivotal role in decomposition, nutrient recycling and forest regeneration. Numerous fungi are dependent on decaying wood, but loss of suitable habitats endangers them. Ecologically sustainable forest management requires knowledge on fungal habitats, their responses to substrate quality and dispersion dynamics. Until now, information about wood-inhabiting fungi has mainly been based on eye-catching fruiting bodies, but nowadays molecular approaches relying on direct DNA extraction from wood have opened a new window to the mysterious world inside logs.

We investigated habitat preferences of dead wood-inhabiting fungi and their possible dispersion from soil. Fungal communities colonizing Picea abies logs representing all decay stages were studied by using direct DNA extraction coupled with high-throughput pyrosequencing.

The results showed that fungal diversity in dead wood is higher than expected; most of the species would not have been recorded in polypore fruiting body inventories and many fungi were unknown. Moreover, fungal diversity increased with decay, suggesting that heavily decayed wood is an important habitat for many fungi. Saprotrophic white and brown rot fungi and symbiotic mycorrhizal fungi all responded differently to decreasing wood density, meaning that these ecological groups have partly distinct niches. We constructed fungal habitat models for identified species. These estimates can be linked to wood decomposition models and forest stand simulators used in forest planning. Dispersion routes will be discussed, but the results already suggest that mycorrhizal fungi dispersed from soil to heavily decayed logs and in the end were a highly dominating group of fungi.

P22

Coarse woody roots harbor asymbiotic N_2 fixation and contribute to forest nitrogen budget

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The rates of asymbiotic N_2 fixation associated with decomposing woody roots have rarely been evaluated and the majority of non-symbiotic N fixation has been measured so far in temperate forests. Based on earlier studies that found N_2 fixation in decomposing wood, we hypothesized that N_2 fixation in decaying roots is possible also in boreal forest. Utilization of stump-root systems for energy production has intensified due to the EU targets for reducing fossil CO_2 emissions. However, the role of stumps in nitrogen cycling is poorly understood.

We measured the rate of N_2 fixation in decaying woody roots of Norway spruce (*Picea abies*) (n = 133) and birch (*Betula pendula/Betula pubescens*) (n = 74) excavated from tree stumps harvested 10 – 15 years ago in eight monitored forest research sites located in the southern boreal climate zone in eastern and southern Finland. Our study showed N_2 fixation activity in decaying Norway spruce and birch roots. Nitrogenase activity ranged between -0.24 and 40.3 nmol/g/d with an overall mean of 2.4 nmol/g/d. High variability of the activity rates was found between roots in all eight stands. In our results, tree species did not affect the nitrogen fixation rate. We also found that moisture content or root size were not factors that could explain the high variability in nitrogen fixation rates between samples.

The observed nitrogen fixation activity in decaying woody roots suggest that the harvesting of stump-root systems for energy production has a negative influence on the forest nitrogen balance and a potentially negative influence on forest growth.

P23

Management affects wild berry yields in Norway spruce and Scots pine stands

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Wild berries represent an important non-wood forest commodity, which provides economic benefits as a source of food, income and export revenues, as well as recreation and leisure services (berry picking). Potential yields of forest berries are affected by forest management that alters stand properties (e.g., light and moisture availability) and survival of pollinators. Recent economic optimization studies take into account the novel ideas in forest management and aim to integrate multiple ecosystem services in their solutions. In this study, we evaluated potential importance of berry yields for forest income. In this study, we impose wild berry yield models on stand development scenarios from a recent economic optimization study that account timber production and carbon sequestration. The current short study did not include berry yields in the optimization problem, but uses output of the optimization study in the analyses of the potential berry yields in different management scenarios.

We showed that berry yield in the managed forests are higher than those in the unmanaged stands. Bilberry yields tend to increase with stand age, while cowberry yields were highest in the young stands and in the stands after intensive thinnings. New management schemes optimized for biofuel production and carbon sequestration might not provide an increase in berry yields compared to conventional management. Net present values of the berry yields were relatively low in comparison to that of timber production and forest carbon sequestration.

P24

Long-term effects of site preparation on soil quality and performance of planted Scots pine on boreal forest sites in Finnish Lapland

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The effects of prescribed burning, patch scarification, disk trenching, and ploughing on soil physical and chemical properties, and on Scots pine needle nutritional status and height growth were studied over a period of 20 years in central Finnish Lapland. A split-plot experimental design with randomized blocks was used (288 plots, 2500 pines ha^{-1}) on 8 experimental areas (4 formerly dominated by pine and 4 by spruce). In ploughed ridges, water retention at saturation, and air-filled porosity both at field capacity and in situ were significantly higher than in the untreated intermediate areas. Water retention characteristics on prescribed-burned plots (scarified manually) did not differ from the other plots (scarified by a bulldozer). In top mineral soil, Ca and Mg concentrations were significantly higher on burned plots than on other plots. Electrical conductivity was significantly higher and pH lower in untreated intermediate areas. Needle N concentration was significantly lower, and Ca and B concentrations higher on burned plots than other plots. On formerly pine sites, soil Ca and Mg concentrations and site preparation enhanced height growth, which was significantly higher on burned and ploughed plots than on disk-trenched plots. On formerly spruce sites, soil water content (negative effect) and air-filled porosity (positive effect) in untreated intermediate areas influenced height growth significantly. The results suggest that site preparation may affect soil properties over two decades. The effects on pine growth were evident on pine sites but not on spruce sites for which heavy site preparations are normally used due to excess soil moisture.

P25

Natural regeneration of the HMT (*Hylocomium-Myrtillus* type) spruce forests in Finnish Lapland

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The thick-moss type (HMT) forests dominated by Norway spruce are typical for northern Finland. These are characterised by high elevation, fine-textured till soil, thick raw humus and moss layer, uneven-aged and sparse old-growth stand, slow growth, and rare seed crops. Natural regeneration of HMT forests under adult trees and even in open gaps has been found to be very slow and sparse. Seedlings are established mainly on woody debris and on exposed mineral soil patches in virgin old-growth forests. We modelled the natural regeneration of Norway spruce and downy birch using four field experiments founded from the early 1970s to 1990s in central Finnish Lapland close to the spruce forest line. Site preparation generally enhanced seedling recruitment and height growth compared with untreated areas on clear-cut strips. On the tilt-ploughed plots, however, increasing the treated area resulted in a decreasing number of seedlings. The same amount of seedlings (1000 seedlings ha^{-1}) as in the untreated areas of clear-cuts was found in the virgin forest. Thinning from below in an old-growth forest led to the worst seedling recruitment, while cutting all the spruces and retaining all the downy birches represented the best. One reason for the better natural regeneration in the experiments of the 1970s compared to those in the 1990s may be the excellent seed crops in the early 1970s. The fencing experiments showed that heavy reindeer browsing is threatening the regeneration of downy birch. This may result in a considerably lower proportion of birch in HMT forests in the future.

P26

GPS-based forest operation management system

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A multipoint set of workers and operation equipment conducts a forest operation outdoors as a team very often. Their locations and directions are interpreted and integrated to grasp the process of operation. The process of a team operation was discussed using GPS data obtained at each working point through working hours. Usual working hours represent around 30 thousand data points per working point, and for a team this figure is multiplied by the number of its members. The processes are evaluated and propose – assisted by PC functions – sequences to divide streaming along the team operation, such as timber logging. This system analyzes the team operation and evaluates it for further improvement. A package of software system was constructed in which fundamental functions were installed and analyze/manage functions implemented.

P27

The role of root rot disease in the conifer decline of Siberia and Far East Russia

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Root rot disease (*Armillaria mellea* s.l., *Heterobasidion annosum* s.l., *Phellinus sulphurascens* Pilat., *Porodaedalea niemelaei* M. Fischer) is the main cause of forest decline. Climate change (increases in surface air temperature, amount and frequency of precipitation, wind load), woodcutting, and anthropogenic pollution are the main reasons behind activation of the root rot pathogens. Sometimes *Armillaria borealis* may parasitize a tree for quite a long time. The reason for this is not clear. It could be due to the low pathogenicity of the strain or high resistance of the tree. An additional important factor promoting the occurrence of root rot disease is the decreasing biological stability of trees caused by limited growth of root systems of *Pinus sibirica, Pinus koraiensis, Abies nephrolepis, Abies sibirica, Picea obovata* in shallow soils (15 – 25 cm) overlying hard rock (East Sayan, West Sayan, Kuznetsk Alatau, Sihote-Alin). An additional important factor promoting the occurrence of *H. annosum* root rot is the presence of loam interlayer among sandy deposits (Minusinsk depression and pinewood of southwest Siberia). This creates favorable moisture conditions for *H. annosum*: water drains during the humid period due to the sandy composition, but water is retained by loam elements during the arid period. The mosaic structure of soil should be taken into consideration at the time of reforestation. Forest decline on shallow soils is preceded by a considerable decrease in tree ring width and an increase in mortality trees at a young age (20 – 40 years).

P28

Pollinator fauna of boreal lingonberry and bilberry redefined

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Berries in addition to mushrooms are Finland's most important Non-Timber Forest Products, NTFPs. Pollination is one of the key factors which determines the yearly berry crops in the forests of the three most commercially important berries: bilberry, lingonberry and cloudberry. Although these berries are the most important NTFPs of Finnish forests and an important component in the Finnish nature-use tradition, there is a vast gap in knowledge of the pollination services for these berries.

Native pollinator populations, many of which are dependent on dead wood, have been vastly affected by both intensified forestry practices and structural changes in Finnish agriculture. Populations have diminished which directly affects the capability to produce fundamental ecosystem services in forest, namely pollination services for forest berries. Though commercially important, the pollination services for the main berry crops, bilberry, lingonberry and cloudberry are vastly unstudied in Nordic countries. Only few papers tackle this issue and there is no broad, detailed view available concerning the pollination processes and species responsible.

In this study that took place in Kivalo research forest in Lapland and in Sotkamo research station in Kainuu, Finland, we aimed to determine the pollinator fauna of both lingonberry and bilberry. This study aims to produce detailed knowledge of the function and meaning of pollination services to native berry crops in the forest ecosystem. Therefore, the pollinator composition for both of the plant species investigated will be discussed thoroughly.

P29

Consequences of acclimating/adaptive tree C-N resource balance on soil and forest carbon stocks under climate change

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Elevating CO_2 concentrations and temperatures imply profound changes to the growth environment of trees. Changing supplies of CO_2 from the atmosphere and N from soils also suggest changes to tree structure. According to the functional balance hypothesis, the phenotypic structure of a tree is an outcome of optimal use of balancing growth resources.

We investigated the consequences of acclimating/adaptive resource allocation of trees to stocks of carbon in soils and forests under changing climate. We applied the OptiPipe model that optimally co-allocates growth resources (photosynthesised C and N acquired from soils) to tree structures so as to yield a maximal NPP for a tree. To do this, we first estimated potential C supply for the optimal allocation model with a simple stand CO_2 and water flux model PRELES. Under the assumption of maximal biomass production, the OptiPipe model found optimal stand carbon stock and biomass growths and turnover to litter. Litter was decomposed with Yasso07 model to obtain steady-state soil C stocks. We further assessed the sensitivity of steady-state soil and forest carbon stocks to assumptions of N availability and release from soils, based on model estimates of temperature sensitivity of decomposition and expert assumptions.

The results will show the consequences of acclimating/adaptive resource allocation to soil and stand carbon stocks under different climate scenarios overlaid on a map of Finland, under different assumptions of N availability and release. The results emphasise the role of acclimation/adaptation of structural-functional features of trees as components of forest C balances under changing climate.

P30

Implementing polypore habitat models into a forest management planning system

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In managed forests, timber harvesting regulates the amount of decomposing wood. Changes in the dead wood supply directly affect the presence of wood-inhabiting species that use it as their substrate. Harvests and consequent dead wood can be simulated with any forest management model, and as such, management-driven changes in the habitat potential can be projected for the future.

Maintenance of species diversity in managed forests requires information about species occurrence probabilities and forest planning tools where this information is integrated with simulations of stand dynamics. We implemented an ensemble of habitat models of wood-decaying fungi (polypores) to simulations of stand and dead wood availability and decomposition, and thereafter to the MELA forest planning system. We asked how biomass harvest from boreal Norway spruce stands influences the dead wood availability and occurrence of wood-inhabiting species in one stand, and how nationwide forest use scenarios with various intensities of biomass harvests influence potential habitats in the whole Finland.

Forest management had a clear and species-specific influence on the occurrence of fungal species, as it directly influenced resources these species utilize. In a managed stand, diversity thrived after final harvesting, but declined to a low level by mid-rotation. Harvest residues and stumps, although low quality substrate for many species, were important for diversity in young stands due to their high quantities. Our study suggests wise temporal management of dead wood supply could support the presence of several species, which are not frequently found in managed forests.

P31

Restoration of low-productive, forestry-drained peatlands – impacts on CO_2 and CH_4 fluxes

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Almost 5 million ha of peatlands have been drained for forestry in Finland. Approximately 20% of this area, consisting mostly of initially treeless or very sparsely treed fens, poor transitional pine mires, and pine bogs, is considered under-productive for profitable wood production, and there is a growing interest in restoring these sites towards functional peatlands and rehabilitating their ecosystem services. For this, restoring the ecohydrology by, e.g., blocking or filling ditches, is generally considered a pre-requisite. However, not much is known about the impacts on greenhouse gas (GHG) fluxes of these restoration measures. Depending on the initial site type, successful restoration is expected to result in a restored or strengthened CO_2 sink, and pristine-like methane cycling functions typical to these ecosystems in their pristine state. As part of an EU-funded LifePeatLandUse project, we measured the GHG fluxes of altogether fifty low-productive sites from early summer to late fall in 2014. These sites include restored, drained, and pristine peatlands on rich and mesotrophic north and mid-boreal fens, mid-boreal bogs and transitional mires, and south boreal bogs. In our presentation, we address the average, site-type specific total fluxes of CH_4 and CO_2, and heterotrophic respiration fluxes of CO_2 for restored peatland types and their drained and pristine counterparts, and discuss their variation against various ecohydrological factors.

P32

Transformation of soil profiles in conditions of forest recovery by infrared imaging technique

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Identification of a soil profile formation is one of the main methods for fundamental investigation of soil genesis. Development of instrumental techniques instead of expert assessments is an important area of research in soil science.

Our study aim is to apply the radiometric technique for the analysis of morphological and physical properties of soils in conditions of forest recovery (i.e., abandoned agricultural areas recovered by forest) in comparison with soil characteristics under natural forests of Siberia.

The study was implemented in central Siberia (Krasnoyarsk region and Republic of Khakassia). The on-ground infrared imaging technique was suggested for soils profile analysis. “Soil profile portraits” in the infrared range were obtained as the distribution of the temperature fields in the soil profile. The first stage of image preprocessing is calibration due to brightness temperature, and the next stage is classification.

To validate the developed technology, the images of 35 soil profiles were obtained for different soil types and different phenological periods and external conditions.

The main results were:

- radiometric image analysis provided additional information on the structure of the soil profile;
- the main soil horizons or sub-horizons could be defined depending on the temperature scale that is selected in the classification procedure;
- differentiation of soil horizon structures has occurred at abandoned anthropogenic soils during the forest recovery process.

The temperature gradient can be described by linear functions, while exponential functions should be applied for abandoned agricultural soils as well for technogenic soil from industrial zones.

The work was supported by RFBR (#14-04-00858).

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Lethal effects of waterlogging on Scots pine appear with delay

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One of the current questions in peatland forestry in Finland deals with maintenance of the ditch network. If ditches are not cleaned in time, and/or if evapotranspiration is insufficient to maintain a low enough ground water table, tree growth will be retarded. Climate change with increased precipitation may set some additional challenges in dealing with this question.

We explored the rate of response of 7-years-old Scots pine seedlings to waterlogging during the growing season. We hypothesized that elevated ground water table and consequent root oxygen deficiency in the middle of the growing season induce physiological and growth responses in roots and shoots with delay. The experiment was carried out in the root lab where soil (commercial peat) and air conditions can be controlled independently. The five-week waterlogging treatment started when shoot elongation was ending but trunk diameter growth still continued.

The first symptoms appeared after three weeks of waterlogging, i.e., decrease of dark-acclimated chlorophyll fluorescence of previous- and current-year needles, decrease of light-saturated photosynthesis and transpiration of current-year needles. The decrease continued throughout the waterlogging phase and after the soil oxygen content had returned to a normal level. Trunk sap flow decreased strongly after a few days when oxygen had returned into the soil by drainage. In that phase, visible symptoms of damage were observed in needles. The live shoot and root biomass decreased and electrical impedance spectra of roots changed due to waterlogging. Finally, two-thirds of the waterlogged seedlings died. In conclusion, the rate of response to waterlogging was slow but once started the seedling responses were stronger than expected.

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Productivity of mixed forest stands on different site types

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The objective was to analyze, with an individual-based simulation model EFIMOD, how differences in the initial proportions of tree species (Scots pine, Norway spruce and white birch) and site fertility and moisture affect carbon sequestration in living biomass and soil. The model was verified with field data, and then simulations were carried out for different site types with distinct initial stocks of soil nutrients and soil climate conditions. To analyse the overyielding of each mixture in comparison to monocultures, we calculated the difference (D_{max}) between expected and observed productivity of mixed stands. Mixed stands were shown to be more productive than monocultures. The effect of species mixtures on NPP was clearly positive in mixtures of coniferous species and also in some of the birch mixtures. The effect was the most remarkable on the most fertile sites. In mixed stands of birch and pine, the values of D_{max} increased with increasing initial proportion of pine. In mixed birch-spruce stands, D_{max} was the highest in the case with equal initial proportions of both species. In mixed pine-spruce stands, the D_{max} value was remarkably higher than 0. In mixed stands of all three species, D_{max} was also > 0, being the highest in the case of initial domination by conifers. In general, in most of the mixtures there was an increase in values of D_{max} from the poor to the rich site. This work was supported by the Russian Foundation for Basic Research, grant number 15-04-05400, and the Academy of Finland, project numbers 140766 and 278151.

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Modelling the spread of the decay fungus *Heterobasidion annosum* in 3-D root systems of Scots pine for fungi management

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In this work, we utilize a three-dimensional structural model for the woody root system of Scots pine. This model describes the root system as a branching structure and it has been implemented as a part of the LIGNUM model. As input the model needs the characteristics of the main roots connected to the stump: diameter, length of the first segment and its spatial orientation. We have added geometrical algorithms to calculate the distance between any two root segments and the existence of root contacts. In addition, a new module spreads the fungus in an infected root system. Furthermore, a module implements the transfer of the fungus to another root system in case of root contacts or if two root segments are close enough to each other. With these new modelling components, it is possible to assess the colonization dynamics of *H. annosum* both in a single Scots pine root system and in a forest stand.

We apply this model to a number of Scots pine stands infected with *H. annosum*. We make simulations indicating how fast the pathogen colonizes pine roots and transmits from one root system to another, consequently producing distribution patterns of the pathogen in time and space. We use these results to outline, for example, silvicultural and biological control methods to prevent the spread of *H. annosum*.

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Effects of open-field warming and precipitation manipulation on leaf phenology of *Pinus densiflora* seedlings

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The objective of this study was to investigate the effects of open-field warming and precipitation manipulation on the leaf phenology of three-year-old *Pinus densiflora* seedlings. Using infrared lamps, temperature in warming plots (w) was increased to be 3°C higher than in control plots (c). Precipitation was manipulated to be 30% lower (p-) or higher (p+) than in the control (p0), using transparent panels and drip irrigation. Two-year-old seedlings were planted in 3-replicated plots for each treatment in April 2013. Leaf phenology was monitored from March 28 to December 4, 2014 at 5 – 7 day intervals. The leaf-unfolding process of individual seedlings was assessed based on a 5-class system (0: closed bud; 1: slight swelling; 2: bud elongated over 2 cm; 3: at least one needle observed; 4: needle grown at the terminal end of new shoot; and 5: terminal needle elongated over 2 cm). The leaf-unfolding in warming plots, with all precipitation manipulations, advanced by 14, 11 and 9 days for stages 3, 4 and 5, respectively. In addition, for abnormal summer new shoot, the occurrence rate of stage 3 and up was higher in warming plots (p0w 21%, p0c 0%, p-w 21%, p-c 1%, p+w 23%, and p+c 0% on December 4, 2014). Previous studies reported that warming causes advanced leaf-unfolding and delayed leaf-fall, while precipitation manipulation showed diverse results. Our observation for leaf-unfolding was similar in response to warming. However, to investigate the overall effects on leaf phenology, more observations for leaf-fall are needed.

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Age-dependent carbon dynamics of Scots pine (*Pinus sylvestris*) stands in Turkey described using a process-based model

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As one of the most dominant tree species in Turkey, Scots pine (*Pinus sylvestris*) forests play an important role as a carbon (C) sink. In spite of this importance, understanding of overall C dynamics in these Scots pine forests is still lacking. Accordingly, by using the process-based model (KFSC model), we elucidated the age-dependent C dynamics of C pools (biomass, litter, aboveground dead wood, and soils) in Scots pine forests. To estimate the growth function of each biomass compartment, a representative tree in each stand was excavated. The KFSC model was modified for the Scots pine stands by substituting some model parameters. The model simulation showed that the C stocks (Mg C ha^{-1}) in biomass gradually increased from 0.3 ± 0.2 at 1 year old to 191.7 ± 113.7 at 200 years old. In contrast, until around 30 years of stand age, the C stocks (Mg C ha^{-1}) in litter, aboveground dead wood, and soils continuously decreased to 8.3 ± 4.8, 2.7 ± 1.0 and 91.2 ± 46.8, respectively. These decreases were attributed to the imbalance between less input and more decomposition of dead organic matter during the early development stage. As vegetation became mature, the C stocks (Mg C ha^{-1}) in these C pools gradually increased from the above values at around 30 years of age to 23.4 ± 13.6, 11.6 ± 5.9, and 100.0 ± 51.6 at 200 years old, respectively. We expect that our study could contribute to the understanding of C dynamics of Scots pine stands.

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Technique and utilization model of sustainable forest management for multifunctional uses

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Forest stand structure is very important for multifunctional forest management. Stand structure indicators, which tend to be associated with spatial location, are a hotspot field of forestry. This paper mainly discusses a quantitative evaluation method for multifunctional forest management, the technology of forest management and its utilization model, and applications in order to maximize forest benefits based on the relationships of stand structure and forest function. As an example, the national forest farm of Jiangle county in Fujian province, China is used. By considering the spatial distribution of forest resources and the relationship of different functions, which was done by applying the principal component method, an index system for forest multifunctional management evaluation was established. In addition, based on the site quality and the biological characteristics of trees, the multifunctional forest management utilization model was also established. The main points are as follows:

1. Establishing forest stand spatial structure parameters promotes the optimization of stand spatial structure in order to make the multifunctional forest grow up rapidly and healthily.
2. Adopting forest stand spatial structure data as the assessment index to determine the dominant forest function enables identification of the direction of the multifunctional forest's development.
3. Analysis of the characteristics of forest spatial structure, the level of forest management and the demand for varieties of forest ecological services is also discussed.
4. Assessment technology in forest multi-functional management and an application model for forest resource optimization are also described.
5. Based on the data analyses, a feasible forest management model was built which can help forest managers to manage stands well.

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Mechanical soil preparation efficiency on the sustainable management of paludified boreal forests

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Paludification is the accumulation of partially decomposed organic matter over formely mesic mineral soils. Paludification reduces tree regeneration and growth, mainly because of low rooting zone temperatures, reduced organic matter decomposition, and hence, low nutrient availability. On the Clay Belt of western Québec and eastern Ontario, forests tend to paludify naturally, but this process might be promoted by logging activities. Our objective was to identify which of two commonly used mechanical soil preparation (MSP) techniques is best adapted to reduce organic layer thickness (OLT) and generate favourable planting microsites post-harvest in paludified sites. Nine experimental blocks (between 20 – 61 ha each) were delimited within a 35 km^2 forest sector with variable levels of paludification. The forest sector was harvested and subsequently the nine experimental blocks were treated with either forest plowing, disc trenching (T26), or left as untreated controls (harvesting only), with three replicate blocks per treatment. We measured OLT before and after MSP, and determined planting microsite quality within each block. Results revealed significant differences in OLT between MSP treatments and harvesting only. Overall, plowing was the best technique, as it reduced OLT more than T26 scarification did, and generated the highest percent of good microsites, except where initial OLT was 44 – 56 cm thick. Our results contribute to improve our knowledge on the sustainable management of paludified forests.

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Financial sustainability of ecosystem-based management in an eastern Canadian boreal forest

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A new forestry regime in Quebec since April 2013 puts emphasis on two fundamental issues: introduction of spatially operating compartments (COS) to agglomerate the harvest and intensification of partial cutting to emulate the natural disturbances more closely. Natural disturbance-inspired management regimes, such as ecosystem-based management, are argued to be capable of maintaining the sustainability of boreal forests at a minimum cost if agglomeration of harvest is properly implemented. However, those studies argue for the intensification of partial cutting to increase the level of biodiversity at all spatial scales. It is widely considered that a landscape with a higher level of biodiversity at different spatial scales is more resilient to environmental stresses such as disturbances and climate change. The main objective of this study was to determine the financial economic potential of implementing ecosystem-based management in boreal forest through financial sustainability criteria.

The specific objectives included: 1) Carry out a cost and benefit analysis (NPV and B/C ratio) of business as usual (BAU) forest management planning; 2) Compare the result of objective 1 with ecosystem-based management (EBM) planning, 3) Carry out the sensitivity analyses with different intensity and distribution of partial cutting as well as variations in model input variables such as costs, revenues and interest rates. A sensitivity analysis was carried out with different proportions of productive area within a COS available for clear cutting (30%, 50% or 70%). Preliminary results showed that increasing the requirement of productive area available for harvesting increased the proportion of partial cutting.

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