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Book of Abstracts - Managing Forests to Promote Environmental Services

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Book of Abstracts

Managing Forests to Promote Environmental Services

Copenhagen, 3- 5 November, 2015

Climate adaptation and mitigation

Clean water

Conservation of biological diversity

'Good' soil quality

Climate change adaptation and mitigation

Carbon sequestration

Water protection

Biodiversity conservation

Soil quality maintenance

UNIVERSITY OF COPENHAGEN

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Nordic Forest Research (SNS)

A Conference arranged by the Centre of Advanced Research on Environmental Services from Nordic Forest Ecosystems (CAR-ES II)

Title
Book of Abstracts - Managing Forests to Promote Environmental Services

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Preface

This book includes the abstracts of the oral and poster presentation of the conference 'Managing Forests to Promote Environmental Services', 3-5 November 2015, Copenhagen. The conference is arranged by the Centre of Advanced Research on Environmental Services from Nordic Forest Ecosystems (CAR-ES II), funded by Nordic Forest Research (SNS) 2011-2015. This is an open network that brings together Nordic and Baltic forest researchers in order to provide scientific knowledge on the impacts of forest management on major environmental services for decision making within the forestry sector and for policy development.

Amongst key environmental services provided by the Nordic and Baltic forests are carbon sequestration, water protection, biodiversity, and soil quality. All these environmental services are affected by various types of forest management, and knowledge on how the forest management can help maintain and enhance these services is crucial to sound decision making in the forest sector and in policy development. Such knowledge will support the forest management in adapting to new conditions in order to continue and increase the provisioning of valuable wood products and clean water, while at the same time maintaining and restoring biological diversity and other environmental services from the forest ecosystem.

The overall aim of the conference is to focus on the interactions between the forest management and the forest's environmental ecosystem services, present the state-of-the-art and identify knowledge gaps. As seen from the abstracts in this book, the contributing researchers will present research on the interaction between forest management and environmental forest ecosystem services as a basis for making decisions about improved forest management in the future. Sessions focus on biodiversity, water protection, carbon sequestration, soil quality, and integrated studies addressing several environmental forest ecosystem services. Key note presentations by Michael Scherer-Lorenzen (University of Freiburg, Germany) and Simon Smart (Centre for Ecology & Hydrology, United Kingdom) link forest management and environmental ecosystem services in a broader perspective, and overviews of ten years of CAR-ES integrated research on carbon sequestration, water protection, biodiversity, and soil quality in the Nordic – Baltic are presented.

Frederiksberg, October 2015

Inge Stupak, Lars Högbom, and Leena Finér

Contents

Poster abstracts Title and authors

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(K1) Biodiversity as a tool for managing forest ecosystem services?

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A number of global change drivers, such as land use change and management, climate change, or air-borne eutrophication, have considerable impacts on the biological diversity of forest ecosystems. Understanding and forecasting the consequences of these changes in biodiversity on ecological processes, functions and the delivery of ecosystem services is certainly one of the major challenges for ecological research. Current research on the functional significance of forest biodiversity suggests a positive relationship between tree diversity and functions related to productivity, associated biodiversity, and soil parameters. However, no and even negative effects were also documented for other ecosystem processes, and many studies find stronger effects of species identity than diversity. In addition, disentangling the diversity signal from confounding environmental heterogeneity remains difficult. Comparisons of tree species performance in pure and mixed plantations imply that changes in light acquisition and plant nutrition may be important underlying mechanisms for the observed diversity effects. The question then arises whether we can design mixed species forest stands that capitalize on the different diversity effects to enhance and stabilize the delivery of multiple ecosystem services. So, can we use the diversity of trees as a tool to manage future forests? This implies consideration of knowledge at very different levels, ranging from species functional traits, interspecific mixing effects, but also trade-offs between different ecosystem services or stand versus landscape perspectives.

(K2) Modelling the potential benefits of expansion of woodlands in Wales

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Major expansion of woodland in Wales (UK) is a major target for the Welsh Government to contribute to a wide range of environments for the achievement of a range of national objectives including combating climate change, improving soil and water quality, connecting habitat patches and improving the aesthetics of the landscape. The inter-dependency between outcomes and how to best optimise their spatial distribution in the landscape is being explored through use of an ensemble of models. Initial work explored the potential benefits of riparian planting with woody species and expanding existing woodland patches. Farmer surveys also identified what the perceived constraints were to uptake of the agro-environment subsidies available for woodland creation. Outputs from the models estimated benefits at a national scale to be: 1 - 9% improvement in flood mitigation; 5 - 10% reduction in greenhouse gas emissions; increased accessible land for 'generic' broadleaf focal species by 3 to 12%, increased national carbon storage by ca. 0.4%, and reduced eroded soil and phosphorus delivery by up to 15% due to reduced connectivity of erodible land to rivers and lakes. A 75% improvement in habitat for 21 selected indicator plant species was also projected but these required 10-20 years to be realised due to a lag time in the response of environmental conditions. A photograph perception survey identified the importance of woodland to quality of landscape but also the limits the presence of woodland could place on visual accessibility of landscape appreciation from public rights of way. Running the payment and assessment activities of the Welsh agri-environment scheme (Glastir) which is the main payment mechanism to encourage the expansion of woodland by landowners, in combination with an integrated monitoring programme and a suite of biophysical and landscape quality models, allows for adaptive management as the Welsh agri-environment scheme progresses.

(1) Biodiversity conservation and ecosystem services in Danish forests. A national analysis

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Biodiversity is declining in Denmark as well as globally. A large fraction of the species of northern temperate areas is naturally adapted to forest habitats. It is estimated that about half of all threatened species in Denmark are found mainly in such habitats. An important threat to the forest biodiversity is intensive forest management aimed mainly at timber production. Thus, halting the loss of biodiversity in general requires an intensified effort to preserve the biodiversity in the forests. An important means to do so is the establishment of more forest reserves, set aside for biodiversity conservation. At the same time, the importance of the forests for timber production cannot be neglected and there is an increasing demand for other ecosystem services such as carbon sequestration and storage, ground water protection, outdoor recreation and biomass for energy production. This raises the general question how to optimize biodiversity conservation and simultaneously pursue several other targets. Answering this question is an important aim of this investigation, in order to support the future forest policy in Denmark and abroad. In quantitative analyses at the national scale we combine data on the distribution of forest dwelling species with data on production of timber and biomass, carbon sequestration and storage, groundwater re-sources, and recreational value. Furthermore, know ledge is compiled on the relation between forest management and ecosystem services. Based on this we answer some specific questions: Which forests in Denmark constitute the most cost-efficient network to ensure the preservation of forest biodiversity? Given the optimal solution for biodiversity, what are the costs in terms of other ecosystem services? Are there geographical patterns in how optimization of ecosystem service values for biodiversity and the other services interact in terms of cost and provision? We present the technical setup of the investigation as well as results on the geographical distribution of the Danish forest biodiversity and other ecosystem services. We also identify important areas for biodiversity preservation and thus, where potential conflicts or synergies are most likely to occur.

(2) Effects of deforestation on litter transport, decomposition rate and invertebrate communities in springfed stream ecosystems in Iceland

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Large-scale deforestation, loss of vegetation cover and subsequent soil erosion has been an ongoing problem in Iceland through centuries. Loss of vegetation and soil does not only affect the function of the terrestrial ecosystems, but can potentially also affect other linked ecosystems, such as freshwater streams in the same area (catchments). The present study was conducted on eight first order headwater streams and their catchments in southern Iceland, where four catchments had been eroded and four had remnant woodland vegetation and soils. Measurements of standing biomass and litter stocks were made and annual terrestrial litter production and litter transport into streams were evaluated. Coarse- and fine-mesh litter bags with leaf litter were put into the streams to measure the decomposition rate and to evaluate the relative impact of aquatic invertebrates on the decomposition rate and the decomposer community structure. Finally the whole benthic invertebrate community in the different streams was evaluated by taking Surber samples. Calculated spatial mean annual aboveground litter production was 13.7 times higher for the remnant woodland catchments than the eroded catchments, but the litter transport into streams was only 2.8 times higher there. This indicated much stronger lateral transport of litter in the more wind exposed eroded catchments. The stream litter decomposition rate was not significantly different between the two catchment types, when only bacteria and fungi were allowed to take part in the decomposition process (fine-mesh litter bags). However, when the invertebrate fauna was also free to access the litter (coarse-mesh litter bags) the decomposition rate was 94% higher in the woodland streams. The overall invertebrate population density, number of species, Shannon-Wiener Index and Index of Similarity did not significantly differ between the two catchment types, neither for the decomposer communities inside the coarse-mesh litterbags nor in the whole benthic invertebrate community. However, in the remnant woodland streams the density of shredders was significantly higher in the coarse-mesh litter bags, partly explaining why the decomposition rates were higher there.

(3) Effects of whole-tree harvesting and stem-only harvesting on plant biodiversity in Norwegian spruce forest sites

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Whole-tree harvest (WTH), i.e. harvesting of forest residues (twigs, branches and crown tops) in addition to stems, for bioenergy purposes may lead to biodiversity loss and changes in species composition in forest ground vegetation, which in turn also will affect soil properties. Effects of clear-cut harvesting on ground vegetation have been investigated at two Norway spruce sites in southern east and western Norway, respectively, differing in climate and topography. Experimental plots at these two sites were either harvested conventionally (stem-only harvest, SOH), leaving harvest residues spread on the site, or WTH was carried out, with the residues collected into piles at the site for six - nine months prior to removal. Vegetation plots in the eastern site were established and analysed before WTH and SOH in 2008 and reanalysed after harvesting in 2010, 2012 and 2014. In the western site vegetation plots were established before WTH and SOH in 2010 and reanalysed after harvesting in 2012 and 2014 (and planned for 2016).All vegetation plots are permanently marked. Pre- as well as post-harvesting species abundances of all species in each vegetation plot were each time recorded as percentage cover (vertical projection) and subplot frequency. Environmental variables (topographical, soil physical, soil chemical, and tree variables) were recorded only once; before WTH and SOH. Effects of WTH and SOH on ground vegetation biodiversity and cover are presented.

(4) How climate change mitigation and adaptation strategies can threaten or enhance the biodiversity of production forests: Insights from Sweden

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Anthropogenic climate change is altering the management of production forests. These changes are motivated by the need to adapt to the uncertainties and risks of climate change, and by the need to enlist their carbon storage and sequestration capacity as part of global mitigation efforts. These changes do however raise concerns regarding the potential implications for forest biodiversity. Here we evaluate these concerns by assessing the biodiversity implications of climate change adaptation and mitigation strategies (CCAMS) being implemented in the production forests of Sweden. We do so by identifying biodiversity goals aimed specifically at closing the existing gap between the habitat requirements of forest-dependent species and the conditions provided by production forests, in terms of tree species composition, forest structures, and spatio-temporal forest patterns. We then use the existing literature to determine whether and by which pathway each CCAMS is likely to bridge or extend this gap. Our results indicate that CCAMS will often come into direct or partial conflict with Swedish biodiversity goals in production forests. Furthermore, CCAMS which are inconsistent with biodiversity goals, such as logging residue removal, are being implemented more extensively than those which were most consistent with biodiversity goals. We nevertheless challenge the necessity of setting the preservation of forest biodiversity against climate change mitigation and adaptation. We clarify how CCAMS with negative biodiversity implications may still be implemented without adverse outcomes, if coupled with conservation interventions, or combined with other CCAMS deemed complementary in habitat provision.

(5) CAR-ES and forest waters, the first 10 years

Högbom, L.[1], Finér, L.[2], Clarke, N.[3], Futter, M.[4], Gundersen, P.[5], Laurén, A.[2], Launiainen, S.[2], Ring, E.[1]

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Questions concerning forest water in general, and the effects of forestry on water in particular, have been among the main issues addressed by the CAR-ES network. Three topics have been highlighted: the water footprint of forest products, management of riparian zones in production forests and collection of Nordic and Baltic data on forests and waters in a joint Nordic/Baltic database. The widely recognized water footprint concept developed by the Water Footprint Network includes evapotranspiration by trees in the water footprint of wood products. Including evapotranspiration in the case of the slow growing boreal forest leads to misinterpretation of the results, this particularly for rain fed ecosystems (Launiainen et al. 2014). CAR-ES has shown that tools for sustainable water management should contextualize water use and water impacts with local water availability and environmental sensitivity.

From an environmental perspective, riparian zones are hot-spots as regards biodiversity and water quality. Within the CAR-ES project we have published an overview describing the function and importance of the riparian zone in Nordic/Baltic forested ecosystems (Gundersen et al. 2010). This has led to increased awareness of the importance of leaving functional buffer zones during forest operations. To get an overview of the existing water and forests monitoring and experimental sites in the Nordic/Baltic countries we have initiated work to compile a meta-database. The database includes observations from more than 400 distinct sites over the whole region. Efforts have focussed on covering all sites where surface, soil and groundwater chemistry measurements from experiments and monitoring sites are available.

Further, there is ongoing work to link the CAR-ES network to other existing international networks on forests, forestry and waters, including application for EU funding (Baltic Sea). In the proposal for a new CAR-ES we will build on the meta-database and utilise the information for future analysis. The development of new analytical and planning tools based on LiDAR, GPS and GIS technologies will enable us to produce tools that will help to reduce the direct impact of logging on surface waters.

Launiainen S, Futter M, Ellison D, Clarke N, Finér L, Högbom L, Laurén A, Ring E (2014) Is the water footprint an appropriate tool for forestry and forest products: The Fennoscandian case. Ambio 43:244-256

Gundersen P, Laurén A, Finér L, Ring E, Koivusalo H, Saetersdal M, Weslien J-O. Sigurdsson BD, Högbom L, Laine J, Hansen K (2010) Environmental Services Provided from Riparian Forests in the Nordic Countries. Ambio 39: 555–556.

Palvianien M, Finér L, Laurén A, Mattsson T, Högbom L (2015) A method to estimate the impact of clear-cutting on nutrient concentrations in boreal headwater streams. Ambio 44:521-531.

(6) Evapotranspiration of forests in Fennoscandia – a synthesis based on eddy-covariance data and modeling

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Evapotranspiration (ET) is a process in which water vapor is transferred to the atmosphere, and has a central role in local, regional and global water budgets and climate. The magnitude of forest ET and its partitioning into various sources is governed by complex interplay between weather conditions, forest structure, species composition and forest management. In this work I combine stand-scale measurements of ET, acquired using a micrometeorological eddy-covariance (EC) method at 15 forest sites in Fennoscandia, with a multi-layer soil-vegetation-atmosphere transfer model. Using the combined model-data approach, I analyze the means and variability of forest ET in Fennoscandia. In particular, I explore how the forest ET scales with leaf area index (LAI) and show that forest floor evaporation to a large extent compensates lower transpiration in sparse or young stands, making dry-canopy ET rather constant over a wide range of LAI. Further, I consider the changes in ET partitioning among transpiration, interception evaporation and forest floor evaporation over rotation cycles, and discuss potential influence of common forest management practices. The work presented is a collaborative effort of Luke and institutions and researchers belonging to the ICOS Finland and Sweden infrastructure. The support from data providers is greatly acknowledged.

(7) Prospects of distributed hydrological modeling in management of forestry drained peatlands

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Peatland drainage has been an important component of forestry management practices in the boreal zone as it improves aeration of the rooting zone, which is considered a key factor for tree growth. The drainage capacity of open ditches gradually deteriorates in time and therefore regular ditch network maintenance (ditch cleaning or complementary ditching) is required in order to sustain tree growth on peatlands. In Finland suspended solid loads following ditch network maintenance cause the largest stress on surface waters by forestry, which has led to the development of water protection structures and avoiding unnecessary maintenance operations. Growing awareness of biodiversity and the existence of low-productive drained areas have lately increased interest towards peatland restoration, e.g. by blocking ditches. Models that can explicitly represent the hydrological interactions in drained peatlands have potential in addressing these matters and provide information to support management practices. In this study, we developed a distributed hydrological model that is suitable for modeling hydrological features in drained peatland forests. The model was implemented by integrating a description of channel network flow to the distributed hydrological FLUSH model that was originally developed for clayey agricultural fields. We applied the model to a 5.2 ha drained peatland forest catchment in eastern Finland which had a recently maintained ditch network with a ditch spacing of 35 m. The model was calibrated and validated against measured discharge, water table depth and ditch water depth for frost-free periods of five months each. Results suggested that the model was able to represent the key hydrological features of a drained peatland forest catchment. The drainage configuration dominated in controlling the spatial patterns of soil moisture conditions, but topography also played an important role and revealed less evident features in the spatial soil moisture distribution. As the model describes the dynamic interaction between ditch water levels and soil moisture conditions, it has potential in assessing impacts of operations in the ditch network on tree growth and peatland water balance. Flow simulation in the ditch network is also a prerequisite for modeling channel erosion and solid transport from drained peatland sites. Estimates of solid transport are needed for the impact assessment of various water protection measures.

(8) Nitrogen leaching after clearfelling and soil scarification at a pine forest nitrogen fertilization experiment, central Sweden

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Forest nitrogen (N) fertilization is practiced in the Nordic countries to increase stem wood production. However, the additional N supplied to forests by fertilization may have consequences for water quality and the acidification of forest soils. Boreal forest which has previously been fertilized with N might be susceptible to elevated N leaching following clearfelling. Here, we studied a Scots pine (*Pinus sylvestris* L.) N fertilization experiment in Sweden during the regeneration phase. The N fertilization treatments were 0 kg N ha^{-1} and 450 kg N ha^{-1} prior to clearfelling of the pine stands in 2006. Following clearfelling, disc trenching was performed creating continuous furrows (F), ridges (R) and areas between two furrows (IB). We calculated soil water leaching fluxes of N during the regeneration phase (2006 – 2011) as affected by previous N fertilization, disc trenching and interactions thereof, by the use of a process-based ecosystem carbon (C) and N model (Coup model; Jansson and Karlberg, 2004; Jansson, 2012). Soil water leaching fluxes of N species and ecosystem mass balances of C and N were calculated by random sampling of the model parameters within previously defined ranges and running the model with the randomly generated parameter sets. Model performance was evaluated by comparing calculated model output with measured soil C and N stocks, plant and field layer C and N and soil water chemistry. We found that, overall, estimates of model parameters were similar for both N treatments and all disc-trenched microsite treatments F, R and IB. Leaching of N (NO_3-N + NH_4-N + dissolved organic N) through the soil profile was 4.8 ±3.2 and 2.5 ±2.5 kg N ha^{-1} $year^{-1}$ in the N fertilization treatments 0N and 450N, respectively, during 2006 - 2011. Disc trenching did not result in increased N leaching in the 0N treatment (4.9 ±3.2 kg N ha^{-1} $year^{-1}$). Based on the calculated ecosystem C and N balance, we conclude that the clear cut was a net source of C and a negligible sink for N during the first six years.

(9) Peatland forests: optimal rotation age, improvement ditching effort and water protection

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This article analyses the optimal forest management and associated water protection measures in peatlands. Forest management measures include final harvesting and improvement ditching. Overland flow fields are considered as a water protection measure. In the theoretical model we analyze the initial stand case, where we consider the case of a social planner with one rotation period. We analyse how the optimal rotation age, improvement ditching effort and optimal size of the overland flow field are chosen simultaneously. In the empirical part of the study we use data of nutrient and sediment loads from Finnish peatland sites to find both the socially optimal solution together with the private optimum solution. The results of the numerical model show that in the private optimum solution whether it is optimal to conduct improvement ditching depends highly on the site characteristics, interest rate, timber price and improvement ditching costs. When we add the nutrient and sediment load damage from harvesting and improvement ditching to the analysis and examine the social optimum we can see that the optimal size of the overland flow field depends on the cost of the overland flow field and the sediment load damage value.

(10) Soil solution quality in a fertilized hybrid aspen plantation cultivated in the agroforestry system in Latvia

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Worldwide, renewable energy is promoted by national and international policies as a contribution to the mitigation of climate change. Agroforestry is a prospective biomass production method which combines simultaneous growing of woody plants with agricultural crops on the same area for different purposes. All extraction of biomass from agricultural lands removes nutrients and reduces acid-buffering capacity as well as possibly causing a decline of water quality both in groundwater and surface waters. Municipal waste products (wastewater sludge) and green energy production side products (wood ash, digestate) are suitable as a compensatory fertilizer to replace lost nutrients and acid-buffering capacity of the soil. However, the ecological risks associated with soil and water contamination with heavy metals during the fertilizing should be quantified and compared with the benefits gained by using biomass for renewable energy production. The aim of this study is to estimate the effect of fertilizers on the soil solution quality in a hybrid aspen (*Populus tremuloides* x *Populus tremula*) plantation cultivated in the agroforestry system in the central part of Latvia. 14 subplots in the large scale multifunctional plantation of short rotation energy crops and deciduous trees with the total area of 16 ha were monitored using suction tube lysimeters to study changes in nutrient and trace metal concentrations in the soil solution following the application of fertilizers during a period of five years. An experimental plot was established on agricultural land in the spring of 2011. Fertilizers used at the planting were wastewater sludge (dose 10 t DM ha^{-1}), wood ash (dose 6 t DM ha^{-1}) and digestate (dose 6 t ha^{-1}).

Establishment of the experimental plot was supported by the European Regional Development Fund's project No. 2010/0268/2DP/2.1.1.2.0/10/APIA/VIAA/118 and continuation of research work was supported by the European Regional Development Fund's project No. 2013/0049/2DP/2.1.1.10/13/APIA/VIAA/031.

(11) Conceptualizing and communicating management effects on water quality in the Swedish boreal forest

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Forestry and other anthropogenic stressors can alter biogeochemical cycles with consequent negative impacts on surface water quality. We present a conceptual framework for evaluating the mechanisms by which anthropogenic activity affects water quality in managed boreal forests and a tool for communicating the severity of this impact. The framework is based on the following catchment processes: Deposition, Weathering, Accumulation, Recirculation and Flux, or DWARF. The magnitude of anthropogenic impacts on the aforementioned processes is assessed in terms of their Extent, Longevity and Frequency; or ELF. Impact severity is communicated using a dashboard based on a "traffic lights" metaphor for characterizing the severity and extent of water quality impairments arising from forestry and other anthropogenic stressors. We apply the DWARF/ELF framework and traffic lights tool to characterize water quality issues in Swedish boreal forests related to forestry and other anthropogenic disturbance on runoff, suspended sediments, dissolved organic carbon, nitrogen, phosphorus, base cations, mercury and organic micro-pollutants (OMPs). The most serious impairments include forestry activities leading to excessive sediment mobilization and associated extirpation of aquatic species and other anthropogenic pressures caused by long range transport of mercury and acidifying pollutants. Because of its already degraded state, any additional nutrient or OMP inputs from Swedish forests to the Baltic Sea are undesirable. The conceptual framework and tool presented here can help evaluate, summarize, and communicate key water quality issues in environments where land management and other anthropogenic stressors combine to impair water quality and may also assist in implementing the "polluter pays" principle.

(12) Soil carbon sequestration in Nordic forestry: influences of changed land-use and management

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Land-use change and forest management effects on biomass carbon (C) stocks are relatively well known, but effects on soil C stocks are more scarcely reported and appear less consistent. Soil organic C (SOC) stocks are spatially variable due to soil heterogeneity and it is a further challenge to detect relatively small changes in large SOC stocks following a change in land-use or management. Forest SOC stocks are largely controlled by the balance between i) above- and belowground litter C inputs and ii) outputs of C by heterotrophic respiration. A land-use change- or management-related effort to sequester SOC in forest ecosystems would need to influence these input or output processes. The demand to account for SOC stock changes following land-use change and the option to account for forest management effects under the Climate Convention and the Kyoto Protocol has led to more SOC research during the last decade. This talk will review some of the evidence regarding SOC sequestration, including results from CAR-ES II during 2011-2015, and identify some challenges for future research.

Forests and land-use change: Does afforestation sequester SOC?

Recent changes in agricultural policies and targeted afforestation programmes have led to natural or planned afforestation of former grassland and cropland throughout Europe (Fuchs et al. 2013). Several recent field-scale and meta-analysis studies have highlighted that rates of SOC sequestration following afforestation depend on previous land-use, e.g. rates of SOC sequestration are higher in afforested cropland than in afforested grassland (e.g. Poeplau et al. 2011). However, uncertainties are large, possibly due to different dynamics within the vast temperate and boreal region. Within CAR-ES, we performed a meta-analysis of afforestation effects on soil C stocks within the Nordic-Baltic region. Based on this synthesis study we concluded that SOC stocks increase, but only after afforestation of cropland and after a lag period of about three decades (Bárcena et al. 2014).

Forest management effects on SOC

A few recent studies have synthesized evidence regarding forest management effects on SOC (Lal 2005, Jandl et al. 2007), but generalizable quantitative information is limited for specific management issues. Some of these are e.g. change in tree species and species diversity, rotation length, management intensity, continuous cover forestry, harvesting intensity and soil drainage. Current trends in forest management may support (reduced drainage) as well as compromise (e.g. whole-tree harvesting) SOC sequestration. A synthesis paper in CAR-ES addressed effects of tree species on soil C stocks in the temperate and boreal regions and concluded that forest floor C stocks can be increased by 200-500% by a change in tree species – conifers store most carbon. Mineral soil C stocks can be increased by 40-50%, but here it seems that

broadleaf species are more efficient in incorporating C into deeper soil layers (Vesterdal et al. 2013). A third synthesis activity was a review of impacts of increased biomass harvesting on SOC stocks within the temperate and boreal regions (Clarke et al. 2015). Increased biomass harvesting may lead to loss of SOC, but such losses may be compensated through targeted management. However, there is much uncertainty and a need for long-term data. The CAR-ES team is currently exploring this topic further through a meta-analysis of effects on soil carbon stores in northern Europe, and the initial results will be presented at the conference.

Future challenges: disentangling mechanisms behind SOC stock differences

For targeted use of land-use change and forest management to sequester SOC we need to move from observational studies of SOC stocks to characterization of the key responsible processes. We must fully understand the processes related to C input and output, particularly belowground, that control SOC stock differences. We should also study forms and stability of SOC along with bulk SOC stocks. Management decisions are based on a wide range of criteria apart from SOC sequestration. Soil C sequestration should be evaluated as one of several ecosystem services to address possible synergies or trade-offs between SOC sequestration and other ecosystem services.

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(13) Carbon sequestration service of boreal forested landscapes. A mapping framework based on GIS and dynamic modeling

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Boreal forests store atmospheric carbon and regulate global climate which is a key environmental service. Mapping the carbon budgets of forested landscapes can be used to identify the trade-offs and synergies between carbon sequestration and various other environmental services. Maps also serve as a communication and visualization tool for stakeholders. The carbon cycle of boreal forests has been studied for decades. Although the effects of forest management on the stocks and flows of carbon are relatively well-known this knowledge has not been adequately implemented in the methods commonly used to assess and map the supply of various environmental services. These methods often assume constant and linearly increasing carbon stocks for land cover classes which may cause remarkably inaccurate estimates. The first aim of this study was to develop a framework for estimating and mapping the current state of the carbon stocks and changes of boreal forests at a regional scale. The second aim was to evaluate the reliability of these estimates in the light of field measurements. The carbon stock of biomass was simulated using the Motti forest stand simulator and that of soil using the Yasso07 soil carbon model. The simulated estimates were mapped using the 20x20 m grid database of the National Forest Inventory. According to this study, the biomass and soil carbon stocks in the study region in 2011 increased at a rate of 0.032 and 0.022 kg C m^{-2} $year^{-1}$, respectively. The mean biomass and soil carbon stocks in the study region in 2011 were 6.567 and 7.909 kg C m^{-2}, respectively. The simulated estimates were in the same order of magnitude with earlier estimates for the whole country in the 1990s. The results indicate that the forests in the study region were managed according to the national forest management recommendations. The mapping framework developed can be used to study both the spatial and temporal variation of the carbon sequestration service in forested landscapes. The estimates are more realistic and accurate than constant values for land cover classes.

(14) Carbon balance of a forest ecosystem after stump harvest

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Stump harvest in forests can cause both reductions of CO_2 emissions through a decrease of decomposable substrate (direct effect) and increases of emissions as a consequence of deep and extensive soil disturbance (indirect effect). We present the effects of stump harvest on net ecosystem CO_2 exchange (NEE) in a former Norway spruce stand in mid Sweden. CO_2 exchange was continuously followed by eddy-covariance measurements during the first years after harvest. Differences in NEE from stump harvested and mounded (reference) plots were determined by soil-surface respiration measurements. Respiration from decaying stumps was estimated by a decomposition model. The fluxes indicated a direct effect (decreased efflux) during the first year after harvest that corresponded to the absence of decomposing stumps. During the following years, this emission reduction was increasingly counteracted by an indirect effect (increased efflux) of similar magnitude. This means that the expected emissions caused by extra soil disturbance occurred with a certain delay and seem to increase with time. By these emissions, the substitution efficiency of stumps as bioenergy is reduced. Furthermore, at a time scale of centuries, instant combustion of stumps leads to a larger contribution to global warming than slow decomposition, because the stump carbon is available earlier in the form of greenhouse gas. This is estimated by the time integral of emissions. Thus, despite the surprisingly low initial emissions, the overall substitution efficiency and climate benefits of stump harvest are likely to be small. The long-term consequences of stump harvest for the carbon budget are, however, still uncertain.

(15) Surface albedo of different vegetation areas in S-Iceland

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Ecosystems provide different environmental services. Among those that are most important are carbon sequestration, water protection and biodiversity. Global warming and its potential impacts on ecosystems is one of the most important environmental concerns of the 21st century. Snow and ice albedo feedback plays an important role in the greater warming of the Arctic compared to the tropics. In 2007, Bala et al, reported that “land uses” like revegetation and forestry in the northern hemisphere actually increased global warming through a change in albedo. This shift in albedo was based on calculations from climate models showing that less snow cover during winter in the northern hemisphere could contribute to a permanent change in albedo and hence increase global warming. No annual measurements on albedo exist in Iceland. In 2012 we started albedo measurements on 4 different surface vegetation areas in S-Iceland. The different vegetation areas are 1) dark sands, 2) revegetated grasslands, 3) deciduous forests and 4) coniferous forests. Permanent measurements on albedo, air temperature and soil temperature have now been ongoing for approx. 3 years. In the presentation preliminary results will be presented and discussed.

(16) Indications that site preparation in the long-term increases overall carbon stocks in coniferous boreal forests but not in their soils

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Mechanical site preparation (MSP) causes a mixing disturbance of the soil, which may increase decomposition of soil organic matter and subsequent carbon (C) dioxide emissions to the atmosphere. However, it also promotes the establishment and growth of new tree seedlings, and hence increases C sequestration by enhanced tree growth and litter production. Consequently, there are uncertainties regarding the degrees to which losses in soil C stocks induced by MSP are balanced by increases in biomass stocks and litterfall. To address these uncertainties, long-term effects of MSP on soil, tree, and total ecosystem C stocks were studied in three field experiments established between 1981 and 1984. Each experiment had a randomized block design with two replicates of treatments consisting of mounding, disc trenching, deep ploughing and control (no disturbance). Following the establishment of treatments, *Pinus contorta* was planted in one experiment (at a site with sandy moraine in northern Sweden), while *Pinus sylvestris* and *Picea abies* were separately planted in the other two (both at a site in southern Sweden with sandy glaciofluvial sediments). The proportion of disturbed soil surface directly after the treatments varied, being ca. 0%, 25%, 50% and 75% in control, mounded, disc trenched and ploughed plots, respectively. At each site, after ca. 25 years the biomass stock was highest after ploughing, intermediate after mounding or disc trenching, and lowest in control plots. Furthermore, due to the positive effects on standing biomass C stock, all of the MSP treatments resulted in larger total C stocks in the entire ecosystem than the control treatment. The mineral soil C stock was lower in the ploughed plots than in the control and disc-trenched plots. However, a theoretical analysis indicated that this finding may have been due to confounding effects of the sampling method. No significant within-experiment differences in C stocks in the top 30 cm soil layer were detected between plots subjected to different MSP treatments. Our general conclusion is that the standing tree biomass had the largest effect on ecosystem C stocks 25 years after treatment. To promote C sequestration the optimal MSP method is the one that maximizes tree biomass production. However, effects on other ecosystem services, e.g. biodiversity, berry production and recreational value, must also be considered in practical forestry.

(17) Impact of alternative forest management regimes and forest supply chain on carbon emissions

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Various studies have been conducted on ideal forest management regimes for optimal economic and environmental value but very few have studied the combination of forest management regimes with use of biomass in different user-sites and its environmental performance. In this study we attempt to determine the environmental impacts (carbon emissions) of biomass products originated from different forest management regimes. The entire supply chain of biomass from forest to the different user-sites is taken into consideration.

Three locations, northern, central and southern Finland, are taken as reference forest of Scots pine (*Pinus sylvestris* L.) stands, with each having five different forest management regimes (mainly with different tree density). The forest development is simulated using MOTTI forest stand simulator whereas impacts related to supply chain are modelled with GaBi software. The timber species are delivered to their destinations, such as pulp factory, energy production plant or saw mills, according to their usability. The different timber species are available from first thinning, other thinning and final felling. The ratio of forest products may vary between the thinnings as well as final felling. Thus, the aim is to study each phase of the forest management and calculate the difference in carbon emissions.

The early phase of the study shows that forest management and supply chain decisions have influence on CO_2 emission reduction potential. The study also shows that the new method combines alternative regional forest management and supply chain streams from the whole forest rotation.

Forest management regime and supply chain decisions should be optimized according to precision forestry and end-use facilities not only for producing cost-efficient timber for industrial and energy purposes but also for producing emission reductions to mitigate climate change.

(18) Soil quality indicators to assess forest management impacts

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The soil quality (SQ) of forest land is a prerequisite for forest ecosystem services which are considered beneficial to society such as carbon sequestration, biodiversity, wood production and water for drinking water production. It is essential to manage the forests in a sustainable way to safeguard the SQ in a long-term perspective. In CAR-ES we have reviewed scientific papers and reports to identify and propose indicators for quantifying and monitoring the impact of silviculture and forest operations on SQ in the temperate and boreal region. Some indicators were described in more detail, including nutrient pools and fluxes (input-output budgets), pH, bulk density, porosity and total carbon contents of the soil. We conclude that biomass harvesting is likely to cause a significant decrease in the soil content of almost all nutrients and an increase in soil acidification, depending on the weathering capacity of the soil minerals and the intensity of harvest as well as the biomass fraction removed. Especially, input-output budgets were found to be appropriate indicators for SQ in relation to the impact of harvesting operations. A change in tree species might also influence the nutrient balance and acidification due to both increases in biomass harvesting and increased deposition of air pollutants. Today's modern intensive forestry includes heavy machine trafficking with great influence on SQ. A macropore volume <10% has been observed to restrict root growth. This critical value for macro-pore volume seems to be a valuable indicator across a wide range of soils, whereas the use of bulk density as an indicator is more difficult since it varies widely even within-site. Many monitoring networks are available worldwide which can be used in future work to identify other critical indicator values. Such monitoring has the potential to increase our understanding of how forestry operations impact SQ and give input to the development of mitigating strategies that can ultimately lead to more sustainable use of the forest soil resource.

(19) Changes of ground vegetation and soil chemical properties after shelter wood cuttings in Scots pine forests

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Sustainable forestry is a significant trend in forestry policy, and there is a growing concern if clear cuttings are sustainable. Silvicultural systems that retain some part of the trees in the stand, such as shelter wood cuttings, have been introduced. The aim of this study was to evaluate early changes of ground vegetation and soil chemical properties after shelter wood cuttings in Scots pine forests in Lithuania. The change in ground vegetation was assessed in shelter wood cuttings of different age along a soil fertility gradient. All species of mosses, lichens, herbs and dwarf shrubs and their projection cover were recorded. The change in organic carbon, total nitrogen, nitrate and ammonium nitrogen, available phosphorus and potassium in the mineral soil was measured in the shelter wood cuttings in different years. Nitrate and ammonium nitrogen in mineral soil were measured in shelter wood, clear cuttings and mature stand. After 5-6 years the number of species in shelter wood cuttings was higher in medium-fertile sites than in very poor sites. After the shelter wood cutting, the abundance of herbaceous species increased in all sites compared to uncut stands. The projection cover of *Vaccinium myrtillus* and *V. vitis-idaea* decreased, while it increased for *Calamagrostis arundinacea*. The abundance of mosses and lichens decreased after shelter wood cuttings in all sites. The changes were more intensive in medium-fertile sites compared to poor sites. Soil organic carbon in the mineral layer in 1–7 year-old cuttings was higher than in uncut stands. Both organic carbon and total nitrogen were slightly higher in 1-5 year-old cuttings. The highest mineral nitrogen concentration was found in clear cuttings compared to shelterwood cuttings. The results confirmed that shelterwood cuttings had weaker negative effect on soil nutrients, especially mineral soil nitrogen, compared to clear cuttings. The effect of shelterwood cuttings on soil nutrients was a short-term effect that lasted up to 5 years.

(20) Effects of elevated N deposition observed after two decades of monthly N-addition to a spruce forest at Klosterhede, Denmark

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The study of long-term effects of elevated N deposition onto forest ecosystems requires long-term experiments. I have maintained a N-addition experiment in a Norway spruce plantation at Klosterhede, Denmark since 1992. Elevated N deposition (35 kg N/ha/yr) was simulated by spraying NH_4NO_3 in monthly doses to a 500 m^2 plot surrounded by three control plots. Over the year 1992 a ^{15}N tracer was added as well both to the N-addition plot and a control plot to study the long-term fate of a one-year cohort of N deposition/addition. In the first decade, the effects of the N-addition on plant and soil parameters were minimal except for a decline in moss cover and some N enrichment of plant compartments. In the second decade, trees started to grow less (c. 25% less) possibly due to impaired nutrition (lower levels of needle contents of P, Ca and K compared to the controls) and effects on the mycorrhizal community. The C/N ratio of the LF layer decreased from 30 to 27 and added N was still (yr 23) largely retained in the ecosystem although the retention efficiency is slowly decreasing. Despite the retention of +700 kg N/ha/yr and a decrease in later-stage decomposition, repeated soil sampling could not reveal any increase in soil C stocks. The fate of the ^{15}N tracer differentiated fast and slow N pools and showed that added N mainly and increasingly over time ends up in soil organic matter. In the presentation I will compare the results from the Klosterhede N-addition experiment with similar data obtained from local and Europe wide gradients in N deposition.

(21) Impact of hydrology and oxygen limitation on forest growth and CO_2 efflux from drained peatlands

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Forest growth in peatlands is typically limited by excess water in the root zone. The growth restriction is a result of decreased oxygen (O_2) availability, which slows down root metabolism, rate of decomposition and nutrient release. Because the decomposition of organic matter is the principal source of nutrients in peatlands, a higher heterotrophic CO_2 efflux indicates higher nutrient release. Therefore, we hypothesize that the CO_2 efflux in peat is proportional to forest growth. We applied Susi-simulator to compute hydrology and CO_2 efflux of forested drained peatland. The simulator computes daily water fluxes and storages in two dimensions for a peatland forest strip located between drainage ditches. The CO_2 efflux is made proportional to peat bulk density, soil temperature and O_2 availability. The hydrological sub-models of Susi-simulator were first parameterized using daily water flux data from Hyytiälä SMEAR II-site, and the predictions then tested against independent hydrologic data from two drained peatland forests in southern Finland. After verification of the hydrologic model, the CO_2 efflux – growth proportionality hypothesis was tested and model performance validated against long-term forest growth and groundwater level data from 69 forested peatland plots in central Finland. Daily weather data, ditch depth and strip width, tree stand characteristics and peat bulk density were available in the experimental data for the simulator parameterization. Growing season median water table depth (DWT) and 5-year stand growth for sample plots located at 5 m distance from the ditch and at the middle of the strip were available for the study. In this phase no further model calibration was performed, and the model predictions were completely independent of the measured data. Two sets of simulations were computed: In Set 1 (from Nov. 1983 to Nov. 1984), the median DWT during the growing season was computed at 5 m distance from the ditch, and at the midpoint of the strip. Measured and modelled median DWT values were plotted to evaluate the performance of the hydrology computation. In Set 2, hydrology, O_2 consumption and CO_2 efflux from the soil along the strip were computed for the period Nov. 1980 to Nov. 1984. Relative CO_2 efflux (R_{CO2}) at the strip midpoint was computed by dividing the local cumulative CO_2 efflux with cumulative CO_2 efflux at the 5 m distance from the ditch. The modelled R_{CO2} was plotted against measured relative volume growth (R_{Iv5}), which was constructed by dividing the 5-year growth (I_{v5}) at the middle of the strip with the I_{v5} at the 5 m distance from the ditch. The results showed a clear relation between the stand growth and CO_2 efflux along the strip. The measured and modelled growth and modelled CO_2 efflux increased towards the ditch, and the relative difference in growth between the strip midpoint and close to the ditch was proportional to the relative difference in the CO_2 efflux. This indicates that management aiming at decreasing heterotrophic CO_2 efflux by raising the DWT will decrease the forest growth. From the C balance perspective the growth rate of the tree stand becomes essential.

(22) Effects of stump harvesting on soil carbon and nitrogen dynamics in relation to surface disturbance

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As a result of changes in international and national energy policy silvicultural treatments which involve extensive biomass removal from forest stands are becoming more common in Scandinavia. The Nordic countries have a long tradition of utilizing their forest resources intensively for both industry and energy purposes and the use of forest-derived biomass for energy has steadily increased in the region during the past 15 years. In the Nordic countries clear-cutting in combination with site preparation is the predominant method before planting after final felling of Norway spruce stands. Stump harvest combined with logging residue removal causes severe soil disturbance, such as mixing and relocation of the organic material and the mineral soil within the soil profile. In addition, stump harvest removes large quantities of biomass from the forest stand. Stumps are long-term carbon and nitrogen stores in a typical boreal forest stand, due to their slow decomposition process. This has raised concerns that stump harvest and logging residues removal could result in large changes in the nutrient dynamics of a forest stand and could eventually lower its site productivity. In this study, the effects of stump harvesting on soil C and N mineralization and soil surface disturbance were studied at two different clear-felled Norway spruce stands in southern Finland. We will present the final results of this study. Treatment effects clearly manifested themselves in the humus layer: the rates of respiration and nitrogen mineralization tended to be higher at all surfaces in the topmost layers of the soil after stump harvesting; however, treatment effect was not significant. The results indicate that stump harvest can have an effect on soil carbon and nitrogen dynamics, particularly on the surface layers of the soil, but further studies are needed.

(23) Carbon and nutrient fluxes from Norway spruce coarse roots and stumps during 40 years of decomposition

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Stumps and coarse roots form the largest part of the coarse woody debris in managed boreal forests but their contribution to nutrient cycling and carbon balance of forest ecosystems is poorly understood. This information is urgently needed for estimating the long-term soil and atmosphere impacts of stump and coarse root removal for energy production. We studied decomposition and nutrient (C, N, P, K, Ca) release from Norway spruce (*Picea abies*) coarse roots (diameters 5–10 cm and >10 cm) and stumps in southern Finland in a chronosequence of stands clear-cut 0, 5, 10, 20, 30 and 40 years ago. Stumps decomposed and released C significantly faster than coarse roots. Stand level assessments suggested that stumps and coarse roots can account for nearly 10% of annual C effluxes in early phases of stand development. The release of N was extremely slow since stumps, >10 cm roots and 5–10 cm roots still contained 97%, 107% and 96% of the initial amounts of N, respectively, after 40 years of decomposition. The amount of P was significantly higher in 40-year decomposed stumps (115%) than in > 10 cm (71%) and 5–10 cm (61%) roots. Stumps and coarse roots lost about 80% of their initial amount of K, and about 50% of their initial amount of Ca during the 40-year period. Nutrient release was greatest during the first 10 years of decomposition. The total amount of N that was released from coarse roots and stumps during the first 10 years was comparable to the annual fluxes by atmospheric deposition, N_2 fixation and N leaching in the Finnish forests but small compared to the annual N mineralization and N uptake by vegetation. The total amounts of P, K and Ca that were released from coarse roots and stumps during the first 10 years corresponded quantitatively to the sum of annual deposition and weathering of these nutrients, and were also considerable compared to annual nutrient uptake of vegetation in sapling stands and annual leaching losses of these nutrients. The results indicate that coarse roots and stumps are long-term C pools and sources of nutrients for vegetation and their removal in harvesting operations will have an impact on the functioning of boreal forests.

(24) Short-term effects of stem-only and whole-tree harvesting on C and N fluxes in two *Picea abies* stands, SE and SW Norway

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Different timber harvesting methods affect inputs of organic matter from branches and tops to the soil. We established two field experiments, SE and SW Norway, to study the effects of conventional stem-only timber harvesting (SOH) and whole-tree harvesting (WTH) on processes affecting the accumulation and loss of soil carbon (C) and nitrogen (N). Logging residues on the WTH plots were collected in piles that were removed after six (SE) or nine months (SW), rendering two sub-treatments (WTH-pile and WTH-removal areas). We weighed selected trees and logging residues, surveyed understorey biomass production, and quantified pre-harvest soil C and nutrient pools down to 30 cm. Soil respiration was measured and soil water sampled monthly during the growing season, while temperature and moisture were measured continuously at 3-hour intervals. Organic and mineral horizons were incubated at different temperatures to estimate potential C and N mineralization, and deep sequencing of the ITS2 barcode region of fungal DNA was performed on the samples. Litterbags were deployed in the SOH plots. At SE, the mean in situ soil respiration rates increased following harvest with all treatments, but were significantly higher in WTH-pile and SOH relative to the WTH-removal areas in the first year as well as the fourth year post-treatment. The increase in the WTH-removal areas may be related to decomposing roots, as well as to higher soil temperatures following harvest. Soil temperature was the most important single factor explaining the variability in soil respiration rates over all treatments. At SW, a decrease in soil respiration was observed with all treatments in the second and third years following harvest. At both sites, decomposition of needles was more rapid relative to twigs and fine roots. A considerable increase in the NO_3-N concentration was observed, including in the WTH-removal areas in the second year following harvest. Saprophytic ascomycetes showed a striking increase in all treatments. The prominent shift in the fungal community was, however, not reflected in the potential C mineralization rates of the forest floor. Generally, the overall effect of harvest seems to be more prominent than the differences between the two harvesting methods.

(25) Protection zones along surface water in the Nordic countries, Estonia and Latvia: A review of legislation and forest certification standards

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The forest landscape in the Nordic and Baltic countries contains not only forests but also numerous lakes, rivers, streams and man-made ditches. The riparian forest plays an important role both for aquatic and terrestrial organisms. Therefore, unharvested strips of forest are preferably left along surface water at harvest operations to provide shade, nutrients etc. to the aquatic system and stabilize the soil and reduce erosion rates. Surface water can also be protected by regulating management and land use adjacent to lakes and streams. In the present study, we examine legislation, forest certification standards and guidelines related to protection zones for surface water in the Nordic countries, Estonia and Latvia. In this region, different types of protection zones are used, ranging in width from 3 to 500 m. We described and analysed how each country defines and designs these protection zones, which are the management requirements, and what is the motivation and rationale behind the design and the requirements. We based our analysis on the policy classification framework proposed by McDermott *et al.* (2009), which makes a distinction between traditional domestic governmental processes (laws and regulations) and private market-based forest certification schemes (voluntary codes of conduct).

McDermott, C.L., Cashore, B., Kanowski, P., 2009. Setting the bar: an international comparison of public and private forest policy specifications and implications for explaining policy trends. Journal of Integrative Environmental Sciences 6, 217-237.

(26) Main findings on environmental services from Lithuanian forest ecosystems

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We present objectives and achievements from four Lithuanian studies related to environmental forest ecosystem services: (1) Forest management: Analyses of the mineral soil solution indicated that in fresh clear cuttings of coniferous stands, especially from skid trails, leaching may cause increased groundwater concentrations of especially nitrate (NO_3^-), nitrite (NO_2^-), potassium (K^+), dissolved organic carbon (DOC) and phosphates (PO_4^{3-}). The leaching of nutrients from arable land with organic farming was similar, except that more DOC was leached in the adjacent forest stands. (2) Intensified harvesting: The national recommendations and legislation on forest fuel extraction and wood ash recycling to the forest and agricultural land were prepared according to the knowledge obtained on bioenergy related issues, such as removal of C and nutrients with forest fuel, and wood ash chemical quality. Recently new maximum values were accepted for micro-elements in wood ash, with thresholds considerably lower than in the Nordic countries. (3) Land use change: Soil organic carbon (SOC) stability in nutrient-poor Arenosols and nutrient-rich Luvisols under different land-use (forest, arable land, afforested arable land, perennial grassland in abandoned arable land) was identified according to the contents of: (i) unprotected SOC (water extractable SOC and SMB-C - soil microbial biomass carbon); (ii) unprotected SOC and SOC being physically protected from microbial decomposition; and (iii) chemically and biochemically protected SOC. We found that the mineral topsoil in afforested arable land along with the highest concentrations of total SOC and SMB-C also contained the highest contents of SOC protected in SOM of silt + clay (<53 µm) fractions. (4) Climate change: We discuss the results from the studies in alien warmth-tolerant forest plantations of red oak (*Quercus rubra*), common beech (*Fagus sylvatica*) and European larch (*Larix decidua*), including productivity, effects on soil, e.g. C sequestration, nutritional status and base cation release.

(27) Sustainability perspectives in forest operations and management: dealing with social, economic and environmental issues.

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This presentation starts off with a description of how loggers and forest stakeholders perceived greater utilization of forest biomass, based on face to face interviews in North America. The interviews covered wood utilization, ecosystem services, effects of biomass utilization, and obstacles to the start-up of large scale biomass utilization from fuel reduction, vs. pile and burn treatments. The presentation then details case studies from the states of Michigan and Tennessee about the operational conditions of the logging workforce in both states. The study is unique because it integrates technical, social, economic and environmental values within the forest products supply chain management. At the end, if time allows, I would hope to have an open discussion with the audience about how the technical, social, economic and environmental aspects of the logging supply chain can impact the ecosystem protective and productive services. What could come out of this is potentially a global dialogue with parameters that investigate how sustainable supply chains can be best developed and integrated with forest best management practices.

(28) Forestry, mercury and good ecological status: What to do when the best is not good enough?

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Forestry operations can increase the biomagnification of mercury in aquatic ecosystems. In Sweden, the concentrations of mercury in the biota exceed the European guidelines for Good Ecological Status in almost all lakes. The problem of high Hg concentrations in the biota, and the contribution of forestry to those high concentrations, is a problem shared by Sweden's Nordic neighbors Finland and Norway. The goal of the forestry-related Hg research has been to find ways to minimize the contribution of forestry operations to the bioaccumulation of mercury in the environment. The great variation in the effects which forestry operations have on Hg outputs, speciation and bioaccumulation holds some prospect that practical ways can be found to minimize the impact of forestry operations. However, the magnitude by which Hg currently exceeds guidelines for safe consumption of fish and especially the exceedance of EU's criteria for good ecological status, means that society's goals with regards to mercury in the environment will not be met, even if forestry operations could be managed to make no contribution to Hg mobilization. This situation with overall goals for mercury in the environment that appear out of reach raises the question of what the goals for the forestry sector should be. Or more specifically, how much should the forestry sector invest in finding and implementing measures to reduce the sector's Hg "footprint", when the overall result will fall short of the mark set by society for good ecological status and/or safe consumption of fish. Thus, Hg represents a class of difficult issues for agriculture and forestry where landscape-based production has a role in a larger issue where the impact of regulating agriculture or forestry needs to be weighed against the contribution which that regulation can have on the overall issue. This paper will consider the challenge of creating an analysis of the forestry sector's role in controlling mercury impacts of forestry given that situation where society will fail to reach its goals for good ecological status regardless of how far forestry can go in reducing the effects of forest management on mercury bioaccumulation. The starting point is the hypothesis that well- framed queries to key actors in the forestry mercury issue could make a tangible contribution to understanding how this issue is addressed in the future from social, regulatory, environmental, entrepreneurial and scientific perspectives.

(P1) Afforestation trials on a cutaway peatland

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After peat extraction has ended, mined peatland must be reclaimed or restored. One of the options for this is afforestation. Forests that have been successfully established on mined peatlands can be used to produce pulpwood or energy wood, and they provide other ecosystem services, particularly in climate regulation. The aim of the study is to determine the effect of fertilizers on tree growth, dimensions and ground vegetation in a cutaway peatland. In 2005, two fertilizer treatments (10 t ha^{-1} waste water sludge and 0.5 t ha^{-1} mineral fertilizers) were applied and seedlings of four tree species (silver birch, Scots pine, Norway spruce and black alder) were planted in plots with a block design. The effect of fertilizer application on tree survival, growth and ground vegetation was examined. Application of fertilizer (soil improvement) was needed for tree survival, growth and afforestation of these areas. However, if successful natural regeneration occurs, planting might not be economically justifiable. The fertilizer type had significant effect on mean height of birch, pine and naturally regenerated trees, but did not have a significant effect on mean tree diameter (DBH). Higher growing stock occurred when fertilized with the organic fertilizer-waste water sludge. Typical forest vegetation had not yet developed ten years after the plots had been established. The vegetation lacked similarity to that of forest, and thus represented a novel man-made ecosystem. Significant differences in morphological parameters occurred between the tree species. Ten years after the trial plot establishment significant differences were observed between the two man-made ecosystems: plots fertilized with sewage sludge and plots fertilized with mineral fertilizer. A lasting effect of the nutrient contents of the rich sewage sludge fertilizer was normal tree growth, which is still continuing after ten years. Cover of moss, graminoids and forbs differed between fertilizer treatments and under different tree species canopies. The positive effect of mineral fertilizer appeared to be ending after the 10-year period. According to the study results, the most suitable tree species for afforestation in cutaway peatlands was Scots pine (*Pinus sylvestris* L.), due to its high productivity in plots fertilized with waste water sludge. However, natural forest regeneration of birch (*Betula* spp.) was successful, indicating its potential in afforestation of cutaway peatland.

(P2) Nordic and Baltic forest soils under change: Soil quality contributions to ecosystem service supply in the light of climatic changes and increasing bioenergy demand

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Coniferous and broadleaved forest or mixed forests, being natural or plantation forest at different management intensities, cover a variety of soils in very diverse climates and parent materials in the Nordic and Baltic region. Although these soils largely share the same glacial history, the postglacial landscape processes have given rise to landscapes and soils with very diverse inherent soil qualities. Current and future changes in climate and forest management will need to take into account the soil resource at the stand level, e.g. with a focus on forest operations that seek to minimize soil damage such as soil deformation, compaction and erosion. Another issue is the need to observe the limitations of the soil nutrient resource. Although remote sensing data will allow more detailed information on surface changes in soils, there will also be a continued need for monitoring of soil quality in the full extent of the tree rooting depth.

(P3) Fine litter decomposition after stem harvest in two *Picea abies* ecosystems: litterbag studies

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Two field studies were conducted to compare ecological impacts of removal vs. non-removal of harvest residues (branches and tops) following clear cut in two Norway spruce ecosystems, one in southwest (SW) and one in southeast (SE) Norway. The SW site was characterized by a steeper terrain and higher rainfall than the SE site. At both sites, litterbags (mesh size 0.15 mm^2) containing 1.7-2.0 g of green needles (age group C+2 to C+4), 1 g twigs (diameter 2-3 mm) or 0.2-1.0 g fine roots (diameter 1-2 mm) were placed in the non-removal plots in May following harvest. Needles and twigs were deployed on top of the forest floor beneath the harvest residues, fine roots between the forest floor and mineral soil layer or at 10 cm soil depth within the forest floor. Needle and twig samples were collected after 3, 6, 12, 24, 36 and 48 months (and 72 months in SE), fine root samples after 24 months.

There was a tendency of a more rapid initial decomposition in SW than in SE. The initial decomposition rate was positively related to the soil humidity measured close to the litterbags. Remaining twig and fine root masses were equal after 24 months on each of the sites, with values 62 % in SW and 71 % in SE. The mass remaining after 72 months in SE was 20 % for needles and 30 % for twigs. The fitted model (first-order decay process) with needle and twig data from the first 48 months showed that within each site, needle decomposition was significantly more rapid than twig decomposition, while there was no significant difference between decomposition rate in SW and SE within each litter fraction. Within the first three years of decomposition, relationships between annual mass loss and litter element concentrations at the start of each year indicated a positive effect of P in needles and twigs and a negative effect of lignin in needles, but no relationship with N or Mn. Decomposition results from litterbags may be reliably used up to a period of six years in the ecosystems studied here. Possible shortcomings of litterbag studies will be discussed.

(P4) LIFE & its contribution to climate change adaptation

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With more than 4 171 initiatives supported to date, 142 projects have been exclusively on climate change adaptation – with a total allocation of €308 million. The LIFE Programme, EU's financial instrument supporting environmental, nature conservation and climate action projects, has tackled possible threats and hazardous events, making a significant contribution to the fight against climate change. Of the many issues addressed by LIFE, there is a focus on practices and measures that promote resilient communities, safeguard natural resources, encourage protection of ecosystems and foster adaptive technologies for economic sectors that are vulnerable to climate change.

CHANGING THE CHANGE

The main aim of the project was to provide information to the Galician agro-forestry sector on the problems of climate change and to promote their involvement in activities that sustain adaptation and mitigation processes. Several benefits were highlighted, such as increase of forest plantation or agri-surface dedicated to agro-fuel crops, increase of carbon content of soil, decrease in the consumption of water and the use of nitrogen through the organization of 41 workshops for key stakeholders, the establishment and monitoring of a series of indicators at 2000 farms & a personalised advisory office in each of the 37 Galician counties (LIFE07 INF/E/000852).

BIOENERGY & FIRE PREVENTION

The main aim of the project was to provide new forest management tools and approaches in order to highlight the wide array of benefits of the protection of Mediterranean forests and their contribution on mitigating climate change impacts. Preventive clear cuts and forest biomass removal were considered for forest fire prevention, while the potential of biomass as a source of renewable energy and rural employment has been also tested and evaluated with significant environmental benefits (LIFE09 ENV/ES/000450).

(P5) Organic beef and other ecosystem services produced at semi-natural pasture and forest mosaics

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Organic produced beef is very much desired by consumers but yet has low economic viability. Our hypothesis is that organic beef production in Nordic countries can be economically viable by creating large, coherent grazing areas including pastures and forests. The project has two aims; the first one is to assess possibilities to make organic beef production in Sweden economically viable by designing coherent grazing land of pastures and forests. The second aim is to evaluate the interplay of the different ecosystem services, i.e. organic beef production versus wood production, climate impact and biodiversity, at the local and national scales. We will assess in what degree wood production might decrease in grazed forests, and whether a reduction can be compensated for by planting trees on set-aside arable land. The assessment of the effect of organic beef production on climate change takes into account the carbon sequestration and greenhouse gas emission of forest, pasture vegetation, soils and cattle. The impact of coherent grazing mosaics on bird, plant and pollinator diversity is also assessed. We will use the concept of ecosystem services to evaluate their interplay; this is a true multidisciplinary approach with economic, forestry, agriculture, biology and soil science expertise included. It is based on literature surveys, experimental trials, participatory methods, national forest and soil inventories and geographical information systems.

The Formas-funded project is carried out 2015-2019 in co-operation with stakeholders such as the Swedish Forest Agency, the Swedish Board of Agriculture, the Pasture Beef Sweden, and the Sjuhärad Rural Economy and Agricultural Society.

(P6) Tree growth and ecosystem services of Hybrid aspen (*Populus tremula* x *tremuloides*) plantings on managed former agriculture land.

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This work is conducted at Skrīveri, a multifunction plantation established in cooperation between LLU Research Institute of Agriculture and Latvian State Forest Research Institute ''Silava''. Soil fertilization was performed after applying fertilizers – ash, sludge, and biogas fermentation residues. The aim of the study is to evaluate the ecosystem services provided by a Hybrid aspen plantation, planted in a 5 by 2.5 m pattern as an agroforestry system with reed canary grass, *Festulolium*, *Galega*; 3 by 3 m as an agroforestry system with grasses and 2 by 2 m as a short rotation coppice (SRC).

Populus spp. is one of three SRC groups of species which are financially supported by a direct support scheme. During the study we measured height and diameter of aspen clone Nos. 4 and 28 (*Populus tremula x tremuloides*) after a four year rotation cycle. During the work we recognized significant differences in tree growth among fertilization methods and clones. It was concluded that the fertilization method using scattering of the fertilizer in soil gave the best effect on the growth and for aspen hybrid No. 4 only the biogas fermentation residues showed a relevant difference compared to the control.

The mushroom *Leccino aurantiaca* appeared in Hybrid aspen plots planted 2 by 2 m during the second growing season. The higher yields of mushrooms were in plots fertilized with waste water sludge and biogas fermentation residues. The content of copper (Cu), lead (Pb), chromium (Cr), cadmium (Cd), arsenic (As) and zink (Zn) in *Leccino aurantiaca* were determined in cooperation with the Faculty of Chemistry of the University of Latvia. Elemental concentrations in solution were determined using flame and electro-thermal atomic absorption spectrometry. Application of different types of fertilizer – sludge, ash and biogas fermentation residues - increases the content of the tested elements in mushrooms compared with the control samples but does not exceed threshold values in national legislation and EU directive No. 2001/22/EC.

(P7) Carbon stock in agricultural soils in Latvia

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The soil organic carbon pool and its reduction due to land use changes and farming activities have a significant influence on the CO_2 concentration in the atmosphere, and thus on global climate changes driven by the greenhouse effect. Land-use changes have a significant influence on the mechanism of carbon balance between the atmosphere and the pedosphere. In Latvia land use changes, particularly conversion of grassland to cropland, is a key source of greenhouse gas (GHG) emissions. According to guidelines of the Intergovernmental Panel on Climate Change (IPCC) reporting of the GHG emissions from key sources should be based on scientifically verified methodology, using country specific and validated emissions factors and data sources.

The aim of this study is to evaluate soil carbon stock in grassland and cropland in Latvia. The study is implemented in the National Forest Inventory plots, where no land-use change was fixed during at least 20 years. In total 120 plots on cropland and 120 plots on grassland were randomly selected. Four sample sets were collected in each sample plot, taking undisturbed soil samples (100 cm^3) at 0-10, 10-20, 20-40 and 40-80 cm depth. Content of inorganic and total carbon is determined in all samples, and additional analyses are done to determine soil type.

Preliminary results of our study indicate that dominant soil types in Latvian grassland and cropland are Stagnosols (28%), Cambisols (26%) and Umbrisols (22%). The mean organic carbon stock in mineral soil at 0-30 cm depth in cropland is 63 ± 2 tonnes ha^{-1} (ranging from 33-110 tonnes ha^{-1}) and in grassland 74 ± 6 tonnes ha^{-1} (ranging from 26-292 tonnes ha^{-1}). According to the study results mean soil carbon losses due to conversion of grassland to cropland at 0-30 cm depth is 11 ± 6 tonnes ha^{-1}. The highest mean carbon content at 0-80 cm depth was found in Gleysols in grassland (250 tonnes C ha^{-1}), Planosols in cropland (150 tonnes C ha^{-1}) and Luvisols in grassland (140 tonnes C ha^{-1}).

The study was implemented within the scope of EEA grants program project "Evaluation of carbon stock in cropland and grassland" (No. 10942).

(P8) Modelling the export and concentrations of organic carbon, nitrogen and phosphorus in boreal lakes by using land cover and land management data

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In boreal lakes the majority of C, N and P is in organic form. Organically bound nutrients are released through biodegradation or photodegradation which affect water quality and greenhouse gas emissions of lakes. A practical computation method for assessing the impact of land use on water quality is needed to support decision making in environmental issues. We tested whether land use data combined with land use-specific export coefficients can be used in the prediction of total organic carbon (TOC), dissolved organic nitrogen (DON) and dissolved organic phosphorus (DOP) loading to boreal lakes. The computation was conducted for 12 lakes in eastern Finland. The land use patterns and annually carried out forest operations in the study catchments represented rather well the land use and forest management in Finland. Land use and management of the catchment explained a substantial proportion of the variation in TOC (r^2 = 0.78), DON (r^2 = 0.55) and DOP (r^2 = 0.80) concentrations between lakes. The results indicated that natural sources dominate TOC, DON and DOP export; the background leaching accounted for 57–99%, 48–96% and 55–99% of TOC, DON and DOP export, respectively. The proportion of peatlands was the most important factor determining the export of TOC, DON and DOP. In the catchments where the proportion of peatlands was low, agriculture was the largest anthropogenic source of TOC, DON and DOP. The significance of forestry was small; it contributed to only ≤1% of the total TOC, DON and DOP export. This may be due to that while forest regeneration increases TOC export, maintenance ditching has an opposite effect. It can be concluded that possibilities for controlling TOC, DON and DOP loading are limited to catchments where peatland proportion is low and anthropogenic sources significant.

(P9) Influence of different tree-harvesting intensities on forest soil carbon stocks in boreal and northern temperate forest ecosystems

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Effective forest governance measures are crucial to ensure sustainable management of forests, but so far there has been little specific focus in boreal and northern temperate forests on governance measures in relation to management effects, including harvesting effects, on soil organic carbon (SOC) stocks. We reviewed the findings in the scientific literature concerning the effects of harvesting of different intensities on SOC stocks and fluxes in boreal and northern temperate forest ecosystems to evaluate the evidence for significant SOC losses following biomass removal. An overview of existing governance measures related to SOC is given, followed by a discussion on how scientific findings could be incorporated in guidelines and other governance measures. The currently available information does not support firm conclusions about the long-term impact of intensified forest harvesting on SOC stocks in boreal and northern temperate forest ecosystems, which is in any case species-, site- and practice-specific. Properly conducted long-term experiments are therefore necessary to enable us to clarify the relative importance of different harvesting practices on the SOC stores, the key processes involved, and under which conditions the size of the removals becomes critical. At present, the uncertainty gap between the scientific results and the need for practically useable management guidelines and other governance measures might be bridged by expert opinions given to authorities and certification bodies.

(P10) Tree species effects on nutrient cycling processes and functional communities in soil at a common garden experiment

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How nitrogen (N) is cycled in forests is important for understanding ecosystem productivity and the role of forests as sinks and sources of greenhouse gases. To determine the effects of tree species on N cycling, we studied two sites within a common garden experiment. We used the ^{15}N pool-dilution method to estimate gross and net rates of N ammonification and nitrification in forest floor soils from western red cedar, western hemlock, Douglas-fir, and Sitka spruce. We used qPCR to determine the bacterial and fungal abundance under each tree species, and the abundance of functional genes associated with nitrification (AOA amoA, AOB amoA) and denitrification (nirS, nirK). Cedar had the highest rates of gross N ammonification and ammonium consumption, followed by spruce, hemlock, and Douglas-fir. All tree species showed net immobilization of nitrate. Site differences in C:N ratios appear to be the primary influence on forest floor microbial biomass C:N dynamics, nitrification and denitrification gene abundance, N ammonification and nitrification rates. Nitrogen ammonification rates were associated with microbial biomass, including microbial C and the abundance of bacterial 16S rRNA genes. Nitrification rates were associated with microbial C and the abundance of AOA amoAgenes, as was the forest floor genetic potential for denitrification. Microbial communities for AOA amoA and nirS differed amongst tree species, while AOB amoA and nirK did not; which suggests that tree species foster different abundances of nitrification and denitrification functional groups, and pools of N. The genetic potential for denitrification was strongly influenced by the abundance of ammonia oxidization potential within forest floors. Functional genetics can be used to explore the mechanistic link between tree species effects on soil microbes, and the nitrogen cycling processes regulated by those microbes.

(P11) The ForHot experiment: Effects of natural soil warming gradients on ecosystem structure and function

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On May 29, 2008, there was an earthquake in Iceland that measured 6.3 on the Richter scale. One of its implications was that geothermal systems were disturbed and moved to new and previously “cold” areas, which increased soil temperature (Ts) at 10 cm depth from +0 °C to +50 °C under both grasslands and planted forest ecosystems. A ForHot pilot project started in 2011, following the ESF-CLIMMANI meeting in Iceland, where participants visited the forest site. By 2014 the ForHot experiment had grown into a large-scale ecosystem study, where three ecosystems were being studied (grasslands with short- and long-term geothermal warming and a Sitka spruce plantation with short-term warming), involving 19 researchers and 13 students. The experimental setup consists of five transects in each ecosystem, each with six permanent plots at ca. Ts +0 (unwarmed control), +1, +3, +5, +10 and +20 °C Ts. The ForHot experiment, with its natural soil temperature gradients, gives an opportunity to study how various ecosystem processes are affected by soil temperature. It is not a prefect simulation of climate change, since the warming only comes from below, but in this system we are able to test our mechanistic understanding of how different plant and soil processes are affected by soil warming.

(P12) Short- and long-term natural soil warming in natural grasslands in Iceland

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In the ForHot project (www.forhot.is), natural geothermal soil temperature (Ts) gradients are used to study Ts dependence of ecosystem processes of Icelandic grasslands. The advantages of these gradients are 1) that short-term (transient) warming effects can be distinguished from long-term (permanent) effects by comparing recently established gradients (that arose after a major earthquake in 2008) and gradients in nearby grasslands where the warming has been ongoing for centuries, 2) that non-linear responses can be identified since we cover a broad temperature range (+0,+1,+3,+5, +10 and +20°C), 3) that the temperature gradients encompass the IPCC RCP scenarios for the sub-arctic. Here we report some key findings of the ForHot-grassland project: (1) Both in the short-term and long-term warmed grassland ecosystem, a loss of soil organic carbon (SOC) of 40% was observed at 5-10 °C soil warming. This provides empirical support that northern grassland could shift into a substantial source of CO_2 in the future. (2) Soil warming (> +5°C) had a pronounced effect on the timing of the onset of the growing season of both the short-term and the long-term warmed grassland. The vegetation greening was advanced by one month in years with warm or moderate spring air temperatures. Cold springs, however, reduced this effect. As the length of the growing season plays an important role in the carbon, water and energy exchange between biosphere and atmosphere at higher latitudes, changes induced by increasing Ts can induce important climate-controlling feedback mechanisms. (3) Increasing Ts caused a decline of vascular plant species richness, where the loss of species was more severe in the long-term warmed grassland (loss of 0.47 species per °C) than in the short-term warmed grassland (loss of 0.25 species per °C). This observation indicates that changes in species composition need time (species deficit).

(P13) Impact of soil warming and N enrichment on ecosystem structure and function in Icelandic grasslands

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A loss of ca. 40 % soil organic carbon (SOC) has recently been observed in Icelandic grasslands warmed naturally by 5-10 °C, which is a realistic predicted temperature increase for high latitudes towards the end of this century. This provides empirical support for a substantial source of CO_2 in the future from such sub-Arctic grasslands, potentially accelerating climate change. A new PhD project of the first author within the ForHot experiment in Iceland (www.forhot.is) aims to unravel the mechanisms behind this observed SOC loss. This will be done by quantifying different input and output SOC processes, the role of concurrent changes in nutrient availability and whether or not the composition of the microbial community matters. Moreover, we aim to study how the ecosystem has adapted structurally (plant and microbial communities, soil bulk density) and functionally (productivity, carbon in- and efflux, closed or open nitrogen cycle) to the soil warming. To investigate whether observed responses to soil warming are mainly temperature driven (direct warming response) or nutrient driven (indirect warming response), a N gradient (+0, +5, +25, +50, +150 kg N ha^{-1} $year^{-1}$) was set up alongside the T gradient (+0, +1, +3, +5, +10, +20 °C), with one treatment where both drivers were present (+10 °C and +150 kg N ha^{-1} $year^{-1}$).

(P14) Annual growth of mature Norway spruce trees grown for three years in elevated [CO_2] at ambient or elevated air temperature and contrasting nutrient availability

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The growth responses of ca. 40-year-old Norway spruce trees to elevated air temperature, elevated [CO_2], and nutrient availability were studied in situ in northern Sweden in two experiments using twelve whole-tree chambers. The first and second experiments studied the interactions between elevated [CO_2] and nutrient availability and elevated [CO_2] and elevated temperature, respectively. After three years of exposure the trees were harvested, the height growth for the last ten years recorded and stem discs were taken and analysed at nine positions along the stems. When nutrients were supplied (Experiment 1), elevated [CO_2] significantly increased the mean annual height increment by 25%, while no significant [CO_2] effect was found at the natural site fertility. After normalising for the between-tree variation in pre-treatment volume growth, the volume growth was significantly increased (28%) by elevated [CO_2] when nutrients were supplied, while there was no significant effect (-10%) at natural nutrient availability. In Experiment 2, which was conducted at the natural site fertility, neither elevated [CO_2] nor elevated temperature significantly affected height increment. There was no effect on diameter or volume growth of elevated [CO_2] at ambient temperature, or of elevated temperature at ambient [CO_2], but a strong interaction between elevated temperature and elevated [CO_2]. This was because elevated [CO_2] only increased volume growth at elevated temperature and vice versa. Across the two experiments, the effect of elevated [CO2] showed an interaction with both nutrient availability (Exp. 1) and elevated temperature (Exp. 2). This indicates that the impact of climate change on productivity of boreal forests will depend both on site fertility and the level of temperature increase.

(P15) Wind and freezing rain damage in forest – impact on fragmentation dynamics: case studies in Latvia

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Biodiversity is a key ecosystem service, dependent on forest structure, including distribution of specific attributes (like deadwood) and types of stands in the forest landscape. Changes of structure of forest landscape depend to a large extent on natural disturbances. Storms are the major natural disturbance in northern Europe. Their impact is predicted to rise in future due to climatic changes. In contrast freezing rain usually affects relatively small areas, but also its impact can be stand-replacing and frequency has not been predicted to decrease due to climatic changes.

Impact of natural disturbances depends not only on stand parameters, but also on the characteristics of a particular event (like amount of freezing rain and wind speeds during it, or maximum wind speeds, their duration and frequency) and other external factors, e.g. if soil is frozen, dry or wet. Therefore results of the study of a specific case have to be generalized with caution; however, it still provides useful insights into effects at landscape scale.

The effect of storm was analysed in forest area (~1600 ha) that was un-managed since 1923 and affected by a large storm in November of 1969. Supervised classification of Corona and Landsat 5 images of the area from years before and after the storm (1966–2010) was carried out and parameters characterizing the fragmentation calculated for 3 land-cover classes: forest, areas with low woody biomass and non-forest areas. It was compared with the recent impact of freezing rain, impacting a similar forest area in December 2011, using stand-level information.

Influence of windthrow on forest landscape was considerable: areas characterized as "forests" (dominant age exceeds that of young stands) were reduced by 53.3 % in the year 1972 (3 years after the storm) in comparison to 1966. Statistically significant influence of storm in land-cover classes was found on mean patch size, mean shape index and mean weighted Euclidean distance. A similar effect of freezing rain was observed. The major part of the analysed unmanaged landscape had returned to land-cover class "forest" already 19 years after the storm. However, changes in Shannon's diversity index demonstrated that fragmentation of the forest landscape had returned to pre-storm state only 30 years after the event. Therefore, if storms are predicted to occur at a frequency less than 30 years, their impact on un-managed (natural) forest landscape could be notable and permanent, changing also the habitat structure.

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(P16) Development of understory vegetation after afforestation on agricultural soil

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In Denmark, former arable land has been afforested during the past 50 years. In 1989, an afforestation program was initiated targeted at doubling the forested area to 25 %. The objectives for afforestation were multifunctional, providing both wood and other ecosystem services such as clean water, biodiversity and near-urban forests for recreation.

To study the development of understory vegetation, we analysed stands of Norway spruce (*Picea abies*), common oak (*Quercus robur*) and beech (*Fagus sylvatica*) from a forest near Copenhagen representing chronosequences of 40-45 years. Five stands of Norway spruce planted in 1969, 1976, 1990, 1998, and 2003, seven stands of common oak planted in 1967, 1976, 1988, 1993, 1998 and 2001 and six stands of beech planted in 1971, 1981, 1990, 1996, 2000 and 2004 were selected. Results were compared to a nearby old growth forest from 1790. Further, we analysed shorter chronosequences in oak and beech on sandy soil. In each stand we measured spring and summer vegetation in 5-m circles, canopy cover, light, and soil chemistry.

The poster will present forest understory and functional trait development in relation to overstory tree species, soil type and time. Further, the poster will discuss management actions to promote floristic diversity in new forests.

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