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Environmental Services provided by the Nordic-Baltic Forests

Extended abstracts of the CAR-ES network meeting in Finland 20.–22.10.2014

Leena Finér, Leena Karvinen and Inge Stupak (editors)

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Tiivistelmä

CAR-ES (Centre of Advanced Research on Environmental Services from Nordic Forest Ecosystems, 2011–2015) is an open network that brings together Nordic and Baltic forest researchers. The CAR-ES network aims at providing scientific knowledge on the impacts of forest management on major environmental services for decision making within the forest sector. The main environmental services addressed are: Carbon sequestration, Water quality, Biodiversity, Soil quality.

CAR-ES organizes meetings, workshops and conferences and the second meeting in 2014 was held in Finland, at the premises of Metla Vantaa Unit. The meeting discussed the issues related to the main environmental services covered by CAR-ES, work on the ongoing subprojects and plannned the final conference as well as the future of the network. The workshop was attended by 30 scientists representing the Baltic and Nordic countries.

The extended abstracts of the presentations are published in this paper.

CAR-ES is funded by the Nordic Forest Research (SNS) as one of its Virtual Centres of Advanced Research.

Asiasanat

biodiversity, carbon sequestration, environmental service, water quality, soil quality

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Yhteydenotot

Leena Finér, Metla, Box 68, FI-80101 Joensuu, Finland, leena.finer@metla.fi from the 1.1.2015
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Muita tietoja

CAR-ES (Centre of Advanced Research on Environmental Services from Nordic Forest Ecosystems, 2011–2015) is an open network that brings together Nordic and Baltic forest researchers. The CAR-ES network aims at providing scientific knowledge on the impacts of forest management on major environmental services for decision making within the forest sector. The main environmental services addressed are: Carbon sequestration, Water quality, Biodiversity, Soil quality.

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On behalf of the organizers

Leena Finér and Inge Stupak

METLA

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(SNS)

Programme of the meeting

Monday 20th of October

13.30 Field Trip Hosted by Pekka T. Rajala and Jukka Koivuluoto, Stora Enso Wood Supply

Visiting Sites:

Lake Löytlammi

- Forest lake in Lake Vihtijärvi watershed in the Karjaanjoki River waterway
- Area 16.6 hectares; 98.3 metres above sea level; shore line 2.28 kilometres
- Peat lands around the lake were ditched manually in the late 1950's
- Water is brownish and contains a lot of humus due to ditching

Regeneration area next to Lake Löytlammi

- The shores of Lake Löytlammi are protected on environmental grounds (MU2, scenery) in the Town Plan of Hyvinkää
- A special harvesting permit was issued by the Town in 2008; the area was harvested in 2009
- A wide (20-metre) buffer zone was left on the waterfront in harvesting; only a few trees prone to wind were extracted.
- The area was scarified and planted some two/three years later

Stream Löytlamminoja (upstream)

- Originally the outlet from Lake Löytlammi may have been a forested trickle
- A proper ditch was dug manually in the connection of drainage in the late 1950's
- Currently the stream/ditch is not regarded as a key habit of the Forest Act
- Regeneration of the stream banks (peat land) using shelter wood method was ordered in the harvesting permit

Stream Löytlamminoja (downstream)

- The same natural/semi-natural stream 2 kilometres downstream
- Water is clear and contains less humus than upstream
- Key habitat of the Forest Act
- Flying squirrels and single old trees are found in the area

Tuesday 21st of October

Venue: Metla, Vantaa Unit, Jokiniemenkuja 1, Vantaa, Finland

8.30 Welcome by Director Jari Varjo, Metla, Vantaa Unit and Dr. Inge Stupak, CAR-ES

Session on carbon and soils, Moderator Leena Finér

9.00 *Effects of geothermal soil warming on soil carbon and nutrient processes in a Sitka spruce plantation*, Bjarni Sigurdsson, Niki Leblans, Edda S. Oddsdottir, Marja Maljanen and Ivan Janssens

9.25 *Carbon and nitrogen storage in small deciduous forest patches over a SW-NE gradient in Europe*, Karin Hansen, Lars Rosenqvist and Filip Moldan

9.50 *Do tree species identity and diversity influence soil carbon stocks in temperature and boreal forests,* Lars Vesterdal, Seid M. Dawud, Karsten Raulund-Rasmussen, Bjarni D. Sigurdsson, Nicholas Clarke and Per Gundersen

10.15 *Coffee break*

10.40 *How to estimate fine root production in peat soils*, Raija Laiho, Rabbil Bhuiyan, Petra Sraková, Päivi Mäkiranta, Tiina Badorek and Timo Penttilä

11.05 *Effects of tree diversity on fine root biomass and production in European forests,* Timo Domisch and Leena Finér

Session on water, Moderator Lars Högbom

11.30 *Forestry and quality of drinking water*, Sirpa Piirainen and Leena Finér

11.55 *Leaf area controls on stand H_2O, energy and carbon exchange over a rotation cycle*, Samuli Launiainen and Saija Huuskonen

12.20 *Lunch*

13.10 *Long-term effects of regeneration cutting and intensive biomass harvesting on nitrogen leaching to groundwater and surface waters,* Eero Kubin, Tanja Murto and Ari Kokko

Session on ecosystem services, Moderator Bjarni Sigurdsson

13.35 *Stump harvest at final felling – impact on soil surface disturbance, and carbon and nitrogen dynamics*, Lilli Kaarakka, Riitta Hyvönen-Olsson, Monika Strömgren, Marjo Palviainen and Heljä-Sisko Helmisaari

14.00 *Coffee break*

14.25 *Growth responses of Picea abies seedlings after whole-tree harvesting and ash addition*, Ulf Sikström, Lars Högbom and Staffan Jacobson

14.50 *Climate change mitigation benefits of intensively managed and untouched forest, Ander Tærø Nielsen*, Walid Fayez Mustapha, Karsten Raulund-Rasmussen and Inge Stupak

15.15 *Ecosystem services in Swedish forests,* Karin Hansen and Mikael Malmaeus

15.40 *Poster session*, 5 min. for each poster

Changes of nutrient concentrations in soil solution in the first year after different types of clearcutting, Sigita Mūrniece**,** Ainārs Lupiķis and Zane Lībiete

Long-term effect of site preparation on soil quality in Tuntsa, Finnish Lapland, Paavo Närhi, Nils Gustavsson, Marja-Liisa Sutinen, Kari Mikkola and Raimo Sutinen

Soil carbon stock change due to drainage of forest stand growing on transitional bog, Andis Lazdiņš, Ainārs Lupiķis and Modris Okmanis

Wednesday 22st of October, Moderator Inge Stupak

8.00	News from different countries, new projects, new activities, persons etc. prepared by the country representatives
9.15	*Plans for the future of CAR-ES*, Inge Stupak et al.
10.00	*Coffee break*
10.25	Future of CAR-ES continues
11.25	*CNP project sum-up*, Lars Högbom
12.30	*Lunch*
13.30	*SNS-WTH project meeting,* Nicholas Clarke, Inge Stupak and Bjarni Sigurdsson
14.00	*Coffee,* Wrap-up session and homework
14.45	Closing the meeting

Participants of the meeting.

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Session on carbon and soils

Participants evaluating a buffer zone in the field trip organized by Mr Pekka T. Rajala and Mr Jukka Koivuluoto Stora Enso Wood Supply. Photo Lars Högbom.

Effects of geothermal soil warming on soil carbon and nutrient processes in a Sitka spruce plantation

Bjarni D. Sigurdsson[1], Niki Leblans[1,2], Edda S. Oddsdottir[3], Marja Maljanen[4] and Ivan Janssens[2]

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Keywords: soil warming; potential decomposition; the ForHot experiment; Iceland; PRS-probes.

Understanding how the ongoing global warming affects the structure and functioning of forest ecosystems is a key challenge of the 21st century, not least because forests play an important role in the global carbon cycle. Simulating warming in manipulation experiments in forests has been criticised for being too small-scale and overly simplistic, whereas surveys which study large-scale temperature gradients in forests often confound temperature with other drivers (Way and Oren, 2010).

Here we present the results from an ongoing soil warming experiment in Iceland where soil temperatures of a Sitka spruce (*Picea sitchesis*) plantation established in 1967 (47 years old) increased at 10 cm soil depth between 0 and +50°C, when a major earthquake in May 2008 moved geothermal gradients into a new, previously cool, area. Five transects were laid out in 2013 with permanent plots located at unwarmed conditions, +1, +3, +5, +10 and +20°C, respectively. Further information about the experimental setup can be found in O'Gorman et al. (2014).

The Sitka spruce trees showed a curvilinear response to soil warming in their growth response. They significantly increased their diameter growth compared to unwarmed control in +1, +3 and +5°C, but had significantly less (77%) diameter growth than at its optimum soil temperatures when the soil warming had increased to +10°C (Figure 1a). The long term mean annual temperature of this region in Iceland is +6.2°C (Icelandic Meteorological Office, 2014), so negative effects on tree growth started to appear when the soil warming was doubling or more the ambient conditions.

Potential litter decomposition, measured as a TBI-Index during the 2014 growing season, increased exponentially as soil warming increased from 0°C to +20°C, and the relative temperature stimulation was higher for easily decomposable litter than recalcitrant litter (higher exponent; Figure 1b).

The increased decomposition would be expected to lead to improved availability of soil nutrients, which would explain the positive growth response seen at the lower soil warming levels. When nitrate (NO_3) and ammonium (NH_4) availability was measured with PRS-probes during the 2013 growing season it was indeed shown that NO_3-N steadily increased with soil warming of up to +5°C, while the NH_4-N stayed relatively unchanged (Figure 2). At excessive warming, +10°C, where the trees were showing reduced growth there was an apparent threshold, above which large quantities of NO_3-N were freely available in the soil (Figure 2).

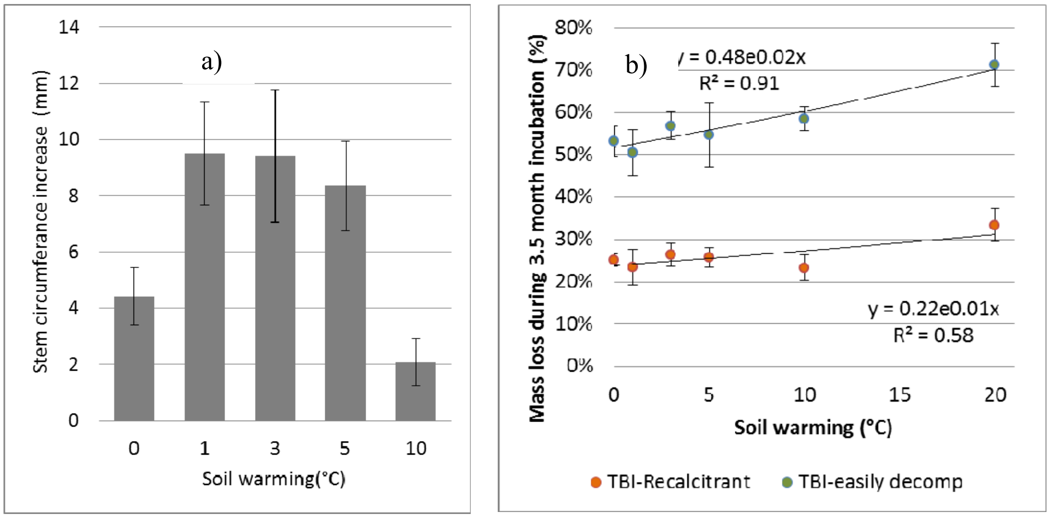

Figure 1. a) Annual change in stem circumference at breast height at different soil warming levels in 2013. Each bar is an average ±SE of 7–10 dendrometers installed on dominant or co-dominant trees. b) Potential decomposition (measured as a TBI) of easily decomposed litter and recalcitrant litter at different level of soil warming during 3.5 months (the growing season) of 2014. Each point is an average ±SD of 5 transects.

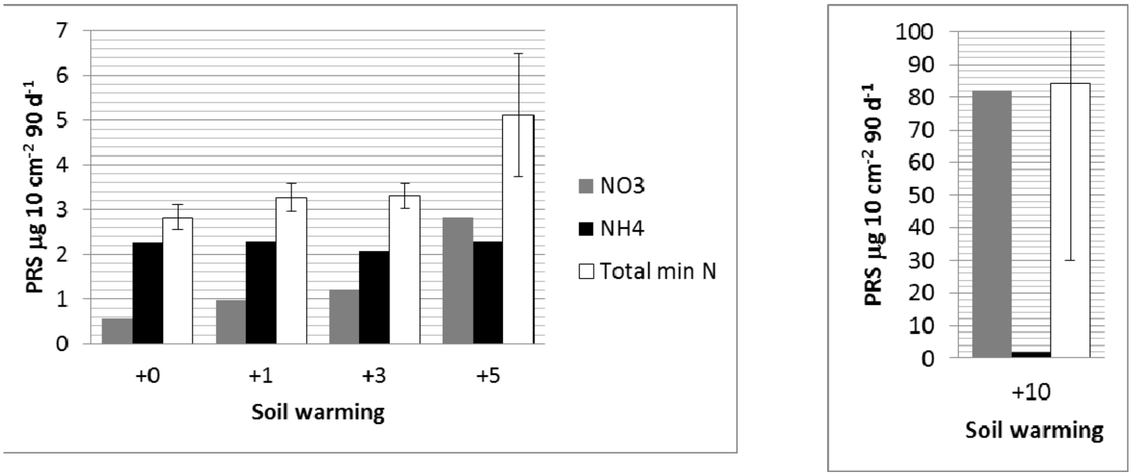

Figure 2. Available NO_3-N, NH_4-N and total mineral N at different soil warming levels during June–August 2013. Each bar is an average (±SE) of 5 plots. Note the different scale on the y–axis for +10°C.

If climate change pushes natural ecosystems over such ecosystem thresholds, where plant demand does not meet the increased availability of nutrients in warmer soils, the consequences can become very dramatic as illustrated with the 30 times increased NO_3-N availability at 10°C soil warming in the present study. This will most certainly induce high risks for nutrient loss from the ecosystems and could cause negative cascading effects, e.g. in freshwater ecosystems receiving the excess NO_3-N, or with negative climate effects if some of this excess NO_3 would be emitted as N_2O. Interestingly it is only at even higher soil temperatures that it has been observed that soil atmospheric N_2O concentrations increase at the site (Maljanen, data not shown).

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Carbon storage in small deciduous forest patches over a SW–NE gradient in Europe

Karin Hansen, Lars Rosenqvist and Filip Moldan

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Keywords: carbon, nitrogen, deciduous forest, forest patches.

Fragmented landscapes generally consist of a mosaic of patches of forests, agricultural land and urban areas creating ecological boundaries within the landscape. Most often, fragmented landscapes are very abundant in most of the low land agricultural dominated regions in NW Europe. As such, small forest patches are common features in the agricultural landscape in Europe. There is limited knowledge of how these small forest patches contribute to carbon (C) and nitrogen (N) storage. Our hypothesis is that small patches of forests contribute significantly to C and N sequestration.

In the ERA-net project called smallFOREST (www.u-picardie.fr/smallforest/uk/) the investigations were conducted in eight regions ranging from southern France to Estonia over a SW-NE gradient, including sixteen 5x5 km landscape sampling windows (two per region) and in total 256 forest patches (Figure 1). The forest floor was sampled along with the upper 10 cm of the mineral soil in all forest patches. A total of 2630 samples were made.

In each region, we analysed C and N concentrations in forest floor and mineral soil as well as bulk density. From this the content of C and N was calculated.

We evaluated the magnitude of C and N content in soils and present data on the C and N content of forest floor and mineral soil along the European transect. We relate data to the age of the forest, the size of the forest patch as well as the distance to the nearest forest edge.

There were no obvious gradient in C concentrations or C contents, in neither forest floor nor the upper 10 cm of the mineral soil. In the forest floor the C concentrations varied between 40 and 50% and in the mineral soil between 3 and 15 %. In the mineral soil the C:N ratio was between 30 and 45. The C content in forest floor was 2–5 t/ha while in the upper 10 cm of the mineral soil it was between 25 and 45 t/ha. The C:N ratios were rather constant throughout Europe, especially in the upper mineral soil where it varied between 10 and 15 (Figure 2).

Figure 1. The gradient of small forest fragment measurement areas in the smallFOREST project – eachplot consisting of a number of small forest patches in a 5X5 km landscape window. Partners from France, Spain, Belgium, Germany, Estonia and Sweden are participating.

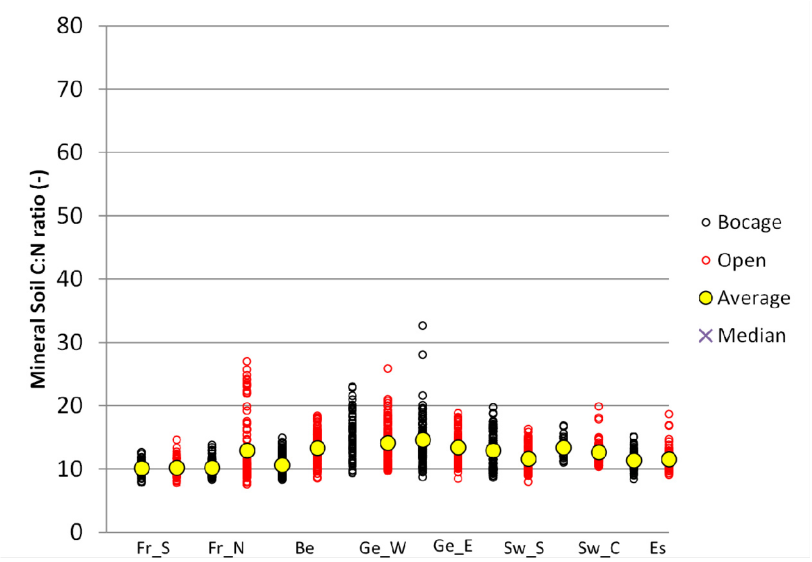

Figure 2. C:N ratio in the mineral soil in the smallFOREST gradient from southern France to Estonia.

Do tree species identity and diversity influence soil carbon stocks in temperate and boreal forests?

Lars Vesterdal[1], Bjarni D. Sigurdsson[2], Nicholas Clarke[3], Per Gundersen[1], Seid M. Dawud[1], Karsten Raulund-Rasmussen[1], Leena Finér[4] and Timo Domisch[4]

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Keywords: tree species, soil C, forest floor, mineral soil, tree species diversity.

Information on tree species identity and tree species diversity effects on soil organic carbon (SOC) stocks is scattered with few attempts to synthesize results for forest floor and mineral soil C pools. We reviewed and synthesized current knowledge of tree species effects on SOC stocks in temperate and boreal forests based on common garden, paired stand and single-tree studies and studied tree species diversity effects on soil C within a large new European research platform.

There was evidence of consistent tree species effects on SOC stocks. Effects were clearest for forest floor C stocks (23 of 24 studies) with consistent differences for tree genera common to European and North American temperate and boreal forests. Support for generalization of tree species effects on mineral soil C stocks was more limited, but significant effects were found in 13 of 22 studies that measured mineral soil C. Proportional differences in forest floor and mineral soil C stocks among tree species suggested that C stocks can be increased by 200–500% in forest floors and by 40–50% in top mineral soil by tree species change (Figure 1).

These proportional differences within forest floors and mineral soils were not always additive: the C distribution between forest floor and mineral soil rather than total C stock tended to differ among tree species within temperate forests. This was seen as an inverse relationship between forest floor C stocks and mineral soil C stocks in temperate tree species experiments that included a wider range of deciduous species (Vesterdal et al., 2008). This suggests that some species may be better engineers for sequestration of C in stable form in the mineral soil, but it is unclear whether the key mechanism is root litter input or macrofauna activity. In the boreal region, where most tree species experiments included only *Picea abies*, *Pinus sylvestris* and *Betula pendula*, a clear pattern of larger forest floor C stocks under *Picea* and lowest forest floor C stocks under *Betula* was proportional to differences reported within the mineral soil. In Denmark, proportional C stocks within forest floor and mineral soil were also reported by Gurmesa et al. (2013) in a comparison of *Picea abies*, *Larix leptolepis*, *Fagus sylvatica* and *Quercus robur* at relatively nutrient poor sites. We mainly attribute these differences in forest floor and C-mineral soil C distribution to the presence or absence of macrofauna species, e.g. earthworms, that are most common on fertile temperate forest sites with deciduous species such as *Fraxinus excelsior*, *Acer pseudoplatanus* and *Tilia cordata* (Vesterdal et al., 2013). In tree species with less affinity to earthworms and in site types with low abundance of macrofauna, there seems to be a positive relationship between forest floor and mineral soil C stocks.

Tree species effects on SOC in targeted experiments were most consistent with results from large-scale inventories for forest floor C stocks whereas mineral soil C stocks appeared to be stronger influenced by soil type or climate than by tree species at regional or national scales.

Although little studied, there are indications that higher tree species diversity could lead to higher SOC stocks. Tree species diversity has been suggested to result in greater productivity and soil C stock due to niche differentiation within ecosystems, but species diversity per se vs. species identity effects remains to be disentangled in rigorous experimental designs. Studies in six European forest types within the FunDivEurope project revealed no strong main effect of species diversity. However, under certain site and climate conditions and in some species combinations SOC stocks increased with species diversity as a support for the niche differentiation hypothesis. Higher root biomass in deeper soil layers (30–40 cm) of species rich forests indicates that higher C input could be one of the main drivers for higher SOC stocks in more species diverse forests.

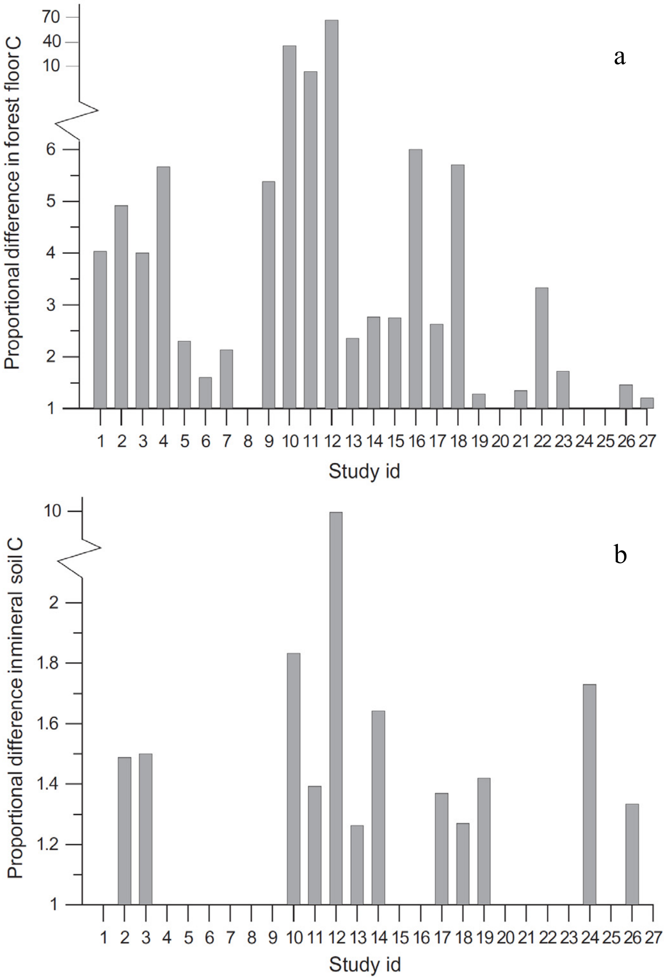

Figure 1. Proportional differences between the maximum and minimum stock of C in (a) forest floors and (b) top mineral soils under different tree species based on studies. Studies 1–18 are from temperate forests and studies 19–27 are from boreal forests. Missing values are due to either missing data ((a) 3 studies, (b) 4 studies) or insignificant ($P > 0.05$) effects of species ((a) 1 study, (b) 9 studies). Vesterdal et al. (2013).

For targeted use of tree species to sequester soil C we must identify the processes related to C input and output, particularly belowground, that control SOC stock differences. We should also study forms and stability of C along with bulk C stocks to assess whether certain broadleaves store C in more stable form. Joint cooperation is needed to support syntheses and process-oriented work on tree species and SOC.

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How to estimate fine root production in peat soils?

Raija Laiho[1], Rabbil Bhuiyan[2], Petra Straková[2] and Timo Penttilä[3]

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Introduction

Emissions of CO_2, and their responses to climate or land-use changes are among the most burning issues in current environmental research. Peatlands represent about 3% of the total land area but a disproportionate 33% of the total soil C pools in this planet. Extensive land-use changes and changing climate are threatening to release some of this C back to the atmosphere. Increased temperatures and lowered water levels might change our peatlands from sinks into sources of CO_2, releasing vast amounts of C stored in the peat soils. This concern has launched intensive research into the C cycle of different types of peatlands. Most of the recent research has been based on C gas exchange studies, which give us valuable insights into the net sink/source function of peatlands.

Gas exchange studies provide only limited possibilities for analyzing the components of the C cycle in more detail. Such information is, however, necessary for understanding the present and, especially, predicting the future behaviour of peatland ecosystems. The soil system where the C transformations take place still largely remains a "black box". A major information gap, leading to high uncertainties in modelling and predictions, lies with below-ground, root-mediated C fluxes: production of fine roots and root litter in peat soils, and their decomposition rates. Nationally, these fluxes are critical because 80% of the soil C in Finland is in peatlands, half of the peatland area has been drained for forestry, and root-related processes in practice determine whether these drained peatland forests are sinks or sources of C to the atmosphere (Ojanen at al. 2014).

This gap in our knowledge concerning the belowground world largely stems from methodological holdbacks. Separating roots from soil and live roots from dead roots is arduous; especially so when it comes to peat soils that solely consist of plant remains, including roots, at various stages of decay. Root production cannot be measured without disturbing the system in one way or the other, which may affect the outcome (Milchunas 2009). Further, the extreme spatial variation (e.g., Finér and Laine 1998) adds to the uncertainty of the estimates. Our aim was to develop a robust method, operating at a yearly time step, that could be used for inventorying fine root production in a wide range of conditions prevailing in the highly diverse habitat types found in peatlands.

Background for choosing the approach

The methods commonly used for estimating root production include sequential coring, ^{14}C-labelling, minirhizotrons, and ingrowth cores or nets; all with their specific drawbacks (e.g., Finér and Laine 1998, 2000, Majdi et al. 2007, Milchunas 2009, Iversen et al. 2012, Rytter and Rytter 2012). None of these methods is as such suitable for monitoring root production in a wide range of peatland types and environmental conditions that would be needed for efficient parameterizing of ecosystem models. Sequential coring involves manual separation of roots from the peat substrate that contains both live and dead roots of a wide age range, and is as such too laborious. Labelling methods are expensive and require special skills, and their results may be difficult to interpret and generalize. Minirhizotrons are generally accepted to be the best method for estimating root lifespan and turnover; however, they involve laborious image analyses and require additional data to obtain area-based production estimates, and are not feasible to use in extensive inventories.

The ingrowth core method involves installing mesh cores filled with root-free soil to holes cored in the ground, lifting these up at certain intervals, and separating and weighing the roots that have grown in and represent production during the incubation period. In the ingrowth net method, cores are replaced by simple nets and roots that have grown through the net during a certain period are used for estimating production (Lukac and Godbold 2010). Both methods have been applied commonly, and their results are relatively easy to interpret. However, even they involve manual separation of roots from the peat substrate, which is the most time-consuming and error-prone phase of such studies. Further, they involve uncertainties associated to cutting the existing root systems at installation, and, in the case of cores, inserting a rather large amount of root-free and thus atypical substrate in the soil. In mineral soil sites, it has been common to use soil cored from the study sites, with roots removed and the original sequence of soil horizons reproduced in the packing of the cores. This is generally not feasible in peatland sites, since root removal would be far too laborious. It is, however, possible to find milled peat without live roots to match different peat soils: non-fertilized horticultural moss peat for bogs, and sedge or woody peat harvested for energy use for fens and swamps. In addition to the nutrient regime, also the bulk density of the ambient soil may be reproduced based on soil sampling to quantify the bulk density in the site. To capture both the production of new roots and the diameter growth of older roots, several years observation period is needed (like in all methods). This brings forth the issue of root mortality, and separating live roots from the dead.

Infrared spectroscopy (IRS) has been found to enable identification of species composition in simple root mixtures (Roumet et al. 2006, Picon-Cochard et al. 2009, Lei and Bauhus 2010). The same holds for separating live roots from the dead (Picon-Cochard et al. 2009). Each chemical bond absorbs IR radiation in a specific manner that depends on the nature of the bond. Thus, an IR absorbance spectrum, showing for each wave-length or wave-number the proportion of radiation absorbed by the sample, shows the relative abundance of different chemical bonds in the sample. The estimation is done by constructing calibration models, regression models based on a calibration data set that consists of samples with known composition plus their IR spectra. These models may then be used to predict the composition of unknown samples based on their IR spectra only. Following the same approach, it should be possible to estimate the mass proportion of roots in a sample consisting of roots and peat, that is, from an unseparated ingrowth core, where peat is used as the substrate. Such samples may be pulverized and homogenized to a sufficient extent that the small samples used for spectral analyses represent the root-peat ratios in the whole cores. The only assumption that has to hold is that live roots share some common chemical patterns that are absent in the peat substrate, and that these chemical differences are quantifiable.

After considering the pros and cons of the different methods, we propose the ingrowth core method and set to modify it so that it would be both less time-consuming and cause less disturbance in the soil system. The idea has been developed based on both our earlier experience on using the method in a more traditional form (e.g., Murphy et al. 2009), testing alternative methods (Lukac and Godbold 2010; data still unpublished). We abandoned the net method for two reasons: difficulties in removing the nets with the necessary amount of undisturbed peat caused by the strong suction of the wet peat soils, and difficulties in obtaining estimates including radial growth and branching of older roots in addition to the production of new roots that the method was designed for. A concise description of the methodology as well as first results from test sites are presented in Laiho et al. (2014).

Suggested methodology and its application

The idea behind the modification has been to decrease the diameter of the cores and to increase the number of replicates. A smaller diameter reduces the disturbance in the soil environment in two ways: the cores may be installed without massive cutting of the root systems, and the volume of the "unnatural" rootless substrate inside the cores is smaller, and may have a smaller overall influence in the root growth patterns. Moreover, a small diameter minimizes delays in the colonization of the cores (Hertel and Leuschner 2002) and thus, reaching the stage where all components of root production are possible. With a large number of replicates, the high spatial variation may be captured and reliable mean values estimated. A high number of replicates may be obtained by applying IRS for estimating the root mass instead of manual separation and weighing.

Cutting of the root systems is avoided by pushing the holes for the cores in the peat instead of cutting. This is possible since peat is predominantly organic matter, and as such, flexible (e.g., Price and Schlotzhauer 1999). Peat volume, and even the position of the peatland surface, depend on and change with the peat water and gas contents (Päivänen 1973, Price 2003, Kellner et al. 2005, Waddington et al. 2010, Kettridge et al. 2013). Thus, the root systems in peat soils need to be flexible as well. We have developed a novel type of two-piece corer-installer for installing the cores (Figure 1). The inner, closed and sharp-end tube pushes the hole to the ground. When the desired depth has been reached, the lock linking the two tubes is released, and the inner tube pulled out. The hollow outer tube then allows us to drop the core into the hole. The inner diameter of the outer tube is 4.4 cm, and we set the theoretical diameter of the cores to 3.2 cm (perimeter 10 cm), so that the core falls freely and when the inner tube is pulled out, the displaced soil closes in around the core. The proper closure and the surface position of the core must be checked. If the closure is not satisfactory, which is possible if the surface is soil dry, the surface soil around the core should be gently compressed around the core. Ideally, the cores are installed in late autumn, after root growth has ceased, to be well settled before the onset of root growth the next year.

The cores are made of flexible polyester mesh fabric; we use mesh size of about 1 mm x 1 mm. The cores are filled with rootless peat matching the soil of the site as closely as possible: unfertilized horticultural *Sphagnum* peat for nutrient-poor (bog) sites, and sedge peat originating from energy peat extraction sites, from deep strata where no live roots have occurred for centennial, for nutrient-rich (fen) sites. When filling the ingrowth cores into target bulk density, measured from the recipient site, we marked 10-cm sections in the cores before filling, measured the dry matter content of the peat substrate, and calculated the amount of fresh mass needed for each 10-cm section, assuming diameter of 3.2 cm, to obtain the desired bulk density (dry mass per fresh volume of soil). Filling was done from bottom up using a wide-mouthed funnel. It is important to note that moss growth may be several centimeters per year even in drained peatland forests (Laiho et al. 2011), so it is important to add some "extra surface" that is left above the soil surface at installation to capture possible root growth inside the evolving moss layer, especially on sites with a vigorous moss layer. Further, it should be noted that there is a short (2–3 cm) section of the filled core that is not fully circular in both the top and the bottom of each core; these should not to be included in the effective length of the core.

At recovery, the position of soil surface is observed and marked in the core; sectioning into 10-cm subsamples is then started from this level at the laboratory. The exact lengths and top and bottom diameters, from two directions, of the subsamples are measured for converting the root mass found in the cores to area–based production values.

The first 3-year test sets of cores that were installed in two intensive research sites have been analyzed (Laiho et al. 2014 and unpublished data). The results showed faster colonization by tree and shrub roots than in traditional ingrowth cores (Finér and Laine 2000, Murphy et al. 2009), and indicate that 2-year incubation is enough for estimating the production.

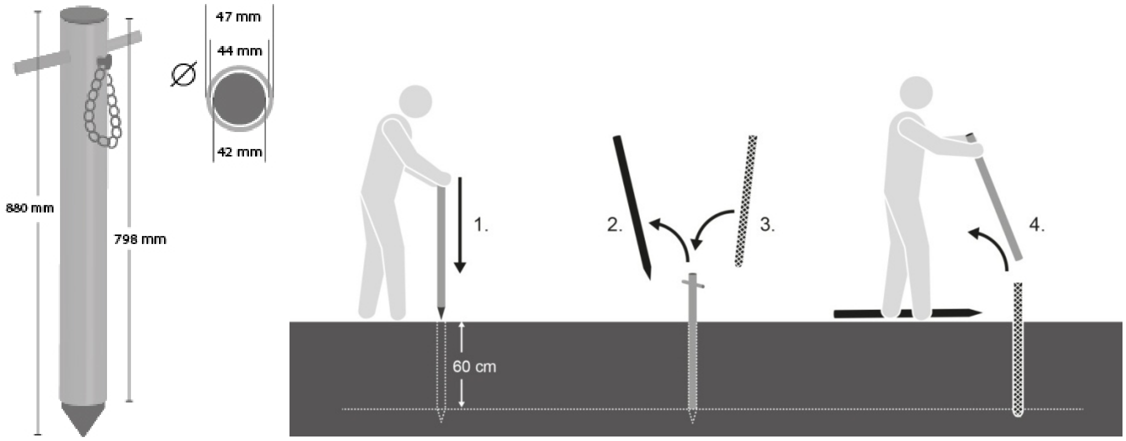

Figure 1. The corer-installer and its utilization. Inner tube in lighter gray, outer tube in darker gray, lock in black. The inner, closed and sharp-end tube pushes the hole to the ground (1). When the desired depth has been reached, here 60 cm, the lock linking the two tubes is released, and the inner tube pulled out (2). The hollow outer tube then allows us to drop the ingrowth core into the hole (3). The diameter of the cores is chosen so that the core falls freely but when the tube is pulled out (4), the soil closes in tightly around the core. From Laiho et al. (2014).

The samples are air-dried and homogenized (pulverization using a ball mill) for the IR analysis. We measured the IR spectra directly from the samples with Vertex FT-IR Spectrometer (Bruker) using Pike MIRacle ATR Crystal detector, in the range 4000–650 cm^{-1}. Mid-IR range was used since this provided the most information and least noise. The models were built by multivariate partial least square (PLS) regression using the Unscrambler software. PLS regression reduces the large number of correlated spectral data into a limited number of principal components (orthogonal components, loading vectors), each representing one independent gradient of variation in the chemical composition of the samples. The principal components are then used as independent variables in a multivariate regression with the measured proportion (%) of in-grown roots in the total ingrowth core mass (peat substrate plus the in-grown roots) used as the dependent variable. The r^2 values and root mean square errors of calibration/prediction were used for estimating the accuracy of the models. For correction of differences in the amplitude and baseline between different runs (samples) we used the Savitzky-Golay, first derivative transformation. Separate models should be built for different peat types, since the chemistry of the peat contributes essentially to the spectra. We observed that when we combined samples with *Sphagnum* and *Carex* peat, systematic error was introduced in the estimation. The error was not great, but peat-type specific models performed clearly better.

The accuracy of the mean production value of a site depends strongly on the number of cores it is based on (Laiho et al. 2014, Figure 8). Between 10 and 30 cores may be needed for the theoretical maximum deviation of the sample mean to drop below 10%, depending on the extent of spatial variation.

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Effects of tree diversity on fine root biomass and production in European forests

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Keywords: biodiversity, tree species, fine roots, species identity, FunDivEUROPE.

Introduction

Many studies underline the importance of biodiversity for ecosystem functioning (e.g. Cardinale et al. 2007), and most of these studies found a higher above-ground productivity with increasing species diversity. However, the majority of these studies concentrated on grasslands. Those studies conducted in forests have found similar results, showing that biodiversity increases above ground productivity, stability and other services of the forest ecosystem (e.g. Brassard et al. 2013). Recent studies have shown that diverse mixed forests can result in higher belowground biomass or production (e.g. Erskine et al 2006). One of the mechanisms leading to increased belowground biomass or production is the niche partitioning between species (Casper & Jackson 1997). However, not all studies found differences between monocultures and mixed forests, and contributed this to a similar soil exploitation strategy of the tree species (e.g. Meinen et al. 2009). Fine roots play an important role in the carbon and nutrient cycling and allocation in forest ecosystems, since up to 75% of the carbohydrates produced by forest trees can be allocated into the fine roots for growth and maintenance (Helmisaari et al. 2002). Despite this high importance of fine roots, little is known about below-ground biomass and production in diverse mixed forests compared to single-species forests. In this study we wanted to quantify the differences in fine root biomass and production between single tree species and mixed forests along a gradient of species richness. Moreover, we tried to identify the mechanisms leading to possible differences by analysing the partitioning of root biomass between different tree species or functional groups (conifers vs. deciduous tree species). We hypothesised that fine root biomass and production would be higher in mixed forests compared to single-species forests, and that higher species richness would result in a more effective utilisation of the soil.

Material and methods

Within the EU-funded FunDivEurope -project, assessing the effects of tree diversity on forest function, we determined tree and understorey biomass in 209, and production in 58 plots of different tree species composition, reaching from monocultures to mixtures of several species (up to five) in six European countries (more details at www.fundiveurope.eu). For determining the fine root biomass, we took nine soil samples from each plot with a corer down to 40 cm if feasible, and the soil layers were divided into layers of 10 cm interval. In most cases we were able to achieve 20 cm in coring depth, only. After transporting the soil samples into the laboratory, the living fine roots (diam. ≤ 2 mm) were separated from the soil, and classified either as tree or understorey roots. After drying at 40°C their mass was determined. The fine root production was determined with the root ingrowth core method. Ingrowth cores were installed at the time of soil sampling and were retrieved after one year. Also here fine roots were separated from the soil and classified either as tree or understorey fine roots.

Results and discussion

Despite some inconsistent trends, we did not find any significant effect of tree species richness on fine root biomass or production within the respective regions (Figure 1 depicts the total tree fine root biomass in the organic and 0–10 cm mineral soil layers). Similarly, we did not find significant effects of species richness in young plantation forests (Domisch et al. 2014). One probable reason for the missing species richness effects might be that the tree species were not different in respect of rooting traits (e.g. Meinen et al. 2009), and thus no niche partitioning was observed. Also the different timing of the soil sampling (May to October) might have masked some of the potential differences. The superficial sampling depth in most cases could have also resulted in the nonexistence of tree species richness effects.

However, there was some evidence, that species identity, expressed either as species composition or functional group (conifers vs. deciduous trees), could be a more important factor explaining fine root biomass and production than only the number of species present in the forest, since conifers seemed to be more competitive in regard of fine root biomass.

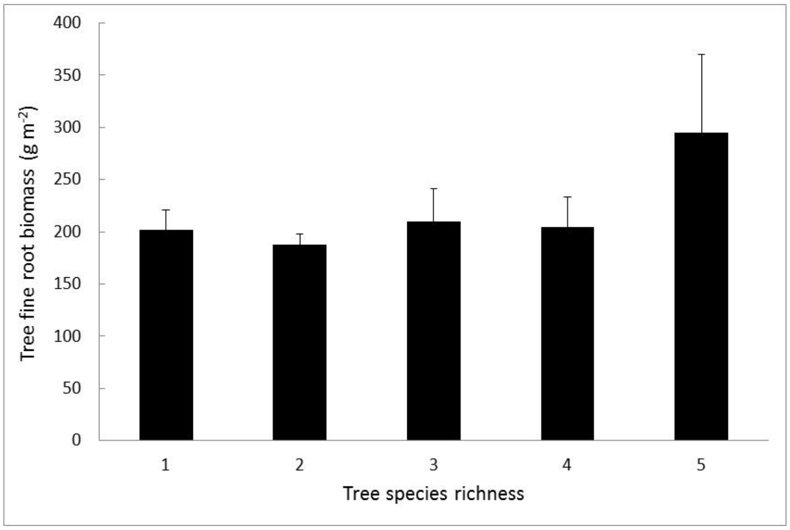

Figure 1. Total tree fine root biomass (g m^{-2}) in the forest floor and 0–10 cm mineral soil layers, as averages in the six study regions and in dependence of tree species richness. Standard errors are depicted.

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Session on water

Stream Löytlamminoja. Photo Lars Högbom.

Forestry and quality of drinking water

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Keywords: ground water, pollution, ecosystem service, boreal forests.

Groundwater is one very important ecosystem service in Finland since 60% of the population water demand is supplied by groundwater. The ground water withdrawal is however much smaller than the supply since only 25% of the replenishment (2.82 Mm^3 d^{-1}) capacity is used. Though, the aquifers near the population centres are the most intensively used and in places water demand exceeds the supply. Groundwater aquifers are mainly located on forest land, thus many forestry operations (fertilization, use of pesticides and herbicides, intensive soil preparation, prescribed burning, stump collection, intensive soil preparation, ditch network maintenance) are not allowed on aquifers to maintain the good quality and quantity of groundwater. Due to shallow soils and other land-uses than forestry, groundwater is vulnerable to anthropogenic pollution. However, the less intensive forestry operations also make quality changes to groundwater especially the nitrate concentrations increases but seldom to the levels jeopardizing household use (Rusanen et al. 2004). Under forests the quality of groundwater is quite stable and mainly good according to the standards set to drinking water. Nevertheless, some problems occur, alkalinity is usually too low and high iron and manganese concentrations are common and in places also high arsenic, fluorine and radon concentrations (Backman 2004). Final cutting change the nutrient cycling in forest ecosystem, nutrient uptake by vegetation is diminished concurrently with substantial supply of nutrients due to decomposition of logging residues. High concentrations of nitrogen, carbon, iron, aluminium, phosphorus and cations have been observed in soil leachates after clear-cutting (Piirainen 2002). At Silkunharju esker in eastern Finland (Figure 1) we study both soil leachtes under the upper soil horizons (0–24 cm) and groundwater (in the depth of 1.5–9.2 m) after final cutting and site preparation. We noticed that although the element concentrations markedly increased in soil leachates the quality changes in groundwater remained small (Figure 2) and the fluctuation in groundwater table level was mainly influenced by precipitation. Forestry operations did not jeopardize the ground water quality for house- hold use, however, e.g. the natural alkalinity was too low for drinking water (Figure 3).

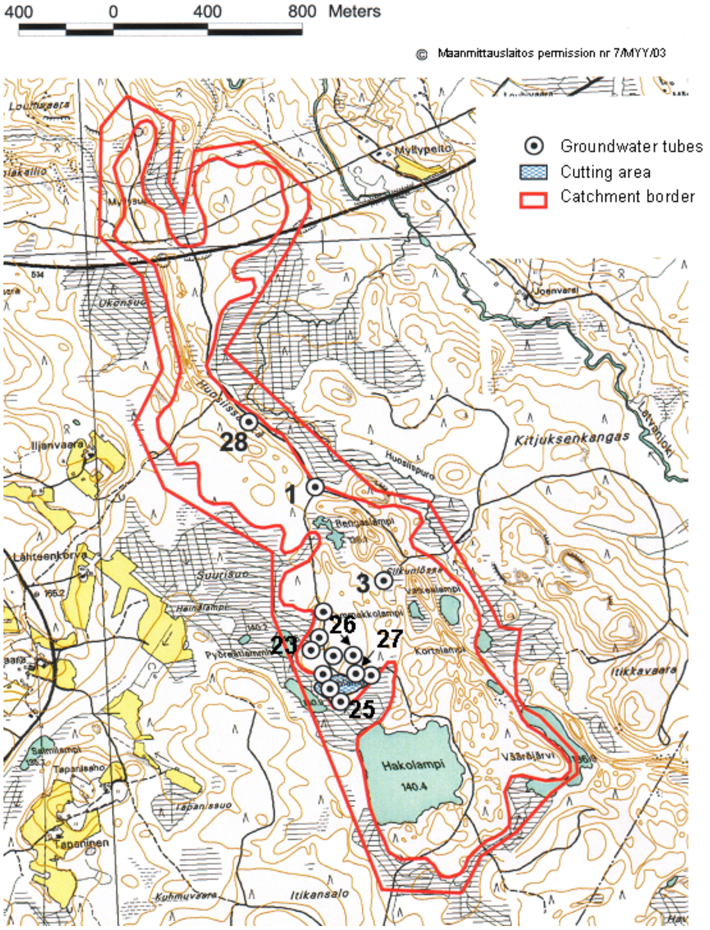

Figure 1. Silkunharju aquifer and the situation of cut area (dashed area) and ground water tubes (circles).

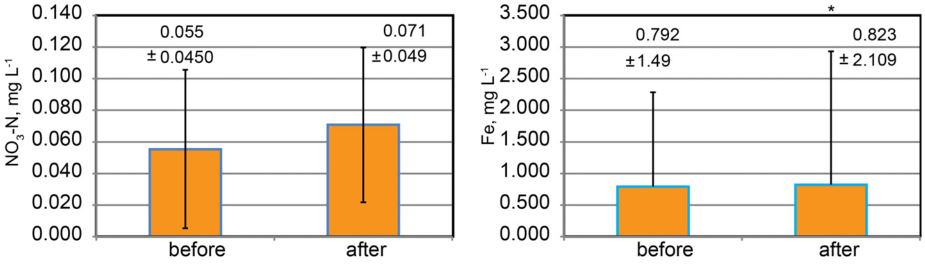

Figure 2. Nitrate and iron average concentrations and standard errors in groundwater before (3 tubes and 9 months during 2000–2001) and after (3 tubes and 10 months in 2001–2003) final cutting and soil carification. Signifigant differences ($p<0.05$) are indicated with *. Final cutting was done in June 2001 and soil carification in August 2002. Figures redrawn from Miettinen 2004.

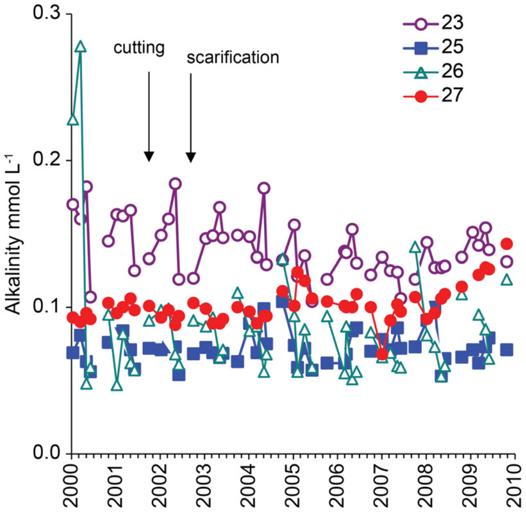

Figure 3. Alkalinity of groundwater on the cut plot at Silkunharju measured in ground water tubes, tube no. 23 is a reference tube.

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Leaf area controls on stand water and carbon exchange over a rotation cycle

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Keywords: evapotranspiration, gross primary productivity, water balance, forest rotation, thinning.

Introduction and methods

Boreal coniferous forests are extensively managed for timber, fibre and to greater extent for bioenergy production. During rotation cycle, ranging from 60 to 120 years depending on site conditions and production goals, stand structure and species composition are altered by growth, natural succession and forestry practices. The changes in stand leaf-area index (LAI, m^2m^{-2}) and its vertical distribution, as well as species-specific physiological characteristics affect within-canopy microclimate and thus leaf-scale mass and energy exchange. It is, however, not well understood how these structural and functional changes manifest themselves when the canopy processes are up-scaled to stand level. To quantify the effects of LAI on water (H_2O) and carbon (C) flows and budgets, a recently developed biophysical multi-layer soil-plant-atmosphere transfer model APES (Launiainen et al., 2014) was used to perform two case-studies.

The first case-study represents thinning of ca. 50 yr Scots pine stand by removing one third of overstory LAI while assuming the vertical LAI distribution remains unchanged. *The second case-study* considers changes in H_2O and C flows over the stand rotation. The statistical forest growth model MOTTI (Hynynen et al., 2005; 2014) was used to compute tree development and management in Scots pine (VT pine, rotation period 82 yr) and Norway spruce (OMT spruce, 62 yr) stands at Juupajoki, Southern Finland. The overstory LAI was estimated from modelled needle biomasses using specific leaf area (SLA) values (Kellomäki et al., 2001). The vertical LAI density profiles were obtained from needle biomass distribution model of Tahvanainen and Forss (2008) developed originally for bioenergy harvesting purposes. The dynamics of field and bottom layer biomass and LAI was calculated by equations of Muukkonen & Mäkipää (2006) using both age and stand characteristics as independent variables. The leaf biomass for dwarf shrubs was estimated assuming that it contributes to 40% (bilberry, heather) – 60% (lingonberry) of total aboveground biomass (Dr. Liisa Kulmala, unpublished data). The leaf-scale physiological parameters of overstory and understory PlantTypes in APES were set to their typical literature values (see Launiainen et al., 2014) assuming physiological characteristics of Norway spruce resemble those of Scots pine, a reasonable assumption in light of available literature.

After site parameterization, the APES was run for two-month (June–July) period representing a moist growing season conditions during which the soil controls on forest-atmosphere interactions are assumed minimal. Finally, since the weather forcing (from Hyytiälä -site at Juupajoki, Finland) and model initial conditions were kept constant for each simulation, the different responses of forest ecosystem reflect only the leaf-area, canopy structure and forest floor vegetation impacts on H_2O and C exchange that frames the scope of this preliminary study.

Results and discussion

Case-study 1: Based on model simulations, the removal of 1/3 of Scots pine overstory leaf area by thinning reduces average daily Scots pine GPP and transpiration rate by 24% and 21%, respectively (Figure 1–2). The productivity and transpiration of field layer dwarf shrubs is, however, increased by ca. 55% in the thinned stand compared to un-thinned. Due lesser competition on light and water resources the remaining leaf area in the canopy layers and at the forest floor is able to photosynthesize more efficiently and to some extent compensate the removed leaf area. At stand scale the average GPP and transpiration are thus decreased only by 18% and 10%, respectively. Since Scots pine density is typically reduced by ca. 40% due thinning, the thinning yields to ca. 25% higher total carbon assimilation per tree, which is of similar magnitude than typically observed increase in volume growth in Scots pine stands in the Southern Finland during the first five years after the thinning. It is also notable that for some days during the dry growing season (Hyytiälä, 2006) simulated here, the GPP and transpiration of thinned stand exceeds that of un-thinned. These periods correspond to conditions when soil water deficits have developed in the un-thinned stand and stomatal and biochemical limitations significantly reduce leaf-atmosphere gas exchange. Although the changes in stand water budget due thinning are relatively small (Table 1), they can be important when soil-leaf feedbacks during a dry growing season are considered.

Case-study 2: During stand rotation the changes in LAI and its vertical profile impact both GPP and ET and their components. In Scots pine stands total over- and understory LAI varies typically from 1.6 to 3.8 m^2m^{-2} and GPP in this range increases roughly linearly with LAI (Figure 3). When also spruce stands are considered, the GPP shows non-linear response to LAI. Assuming physiology of Scots pine and Norway spruce similar, the stand GPP doubles when LAI increases from <2 to >9 m^2m^{-2}. The forest floor and bottom layer contribution to GPP is largest (ca. 20%) in sparsest pine stands but drops to few percentage in dense spruce stands due lesser light availability and lower living forest floor biomass. Also stand ET increases non-linearly with LAI but is less sensitive (+57%) than GPP in the considered LAI range (Figure 3). The forest floor has larger influence to stand ET than GPP. Moreover, the differences in field and bottom layer vegetation lead to higher relative contribution of forest floor ET in young spruce stands than mature pine stands having the same LAI.

The ET components show strongly different responses to LAI (Figure 4). Stand transpiration saturates at LAI ~5.0 m^2m^{-2} and in denser canopies neither growth nor thinning does create marked changes in total transpiration rate. On the contrary, interception and subsequent free evaporation from the canopy shows strong and near-linear dependency on LAI. In virtually all rainfall interception models the total interception storage is assumed linearly proportional to LAI, however, the model simulations suggest that in dense stands the lower canopy layers do not always have sufficient time to fully dry between rainfall episodes creating the slightly curved response of cumulative interception to LAI (Figure 4). Also, the 'scatter' at high LAI shows that vertical structure and height of the stand have stronger impact on interception than to other water balance components. This is mainly due to effect of canopy medium on momentum absorption and resulting changes in within-canopy wind flow and turbulent transport affecting wind speed, temperature and moisture profiles within forests. The simulations show that both moss evaporation and direct soil evaporation decrease slower with LAI than does the physiologically regulated transpiration rate. The evaporation rate from the moss layer and soil are passively controlled by microclimatic conditions at the forest floor (i.e. atmospheric demand and transport), as well as on moss canopy structure and its interactions with underlying soil and its physical state.

The two case studies provide a preliminary analysis on the role of stand leaf area and its vertical distribution on H_2O and C flows in managed boreal forests. They suggest that forest management operations such as thinning can have significantly different impacts to forest-atmosphere exchange depending whether sparser pine stands or denser, closed-canopy spruce stands are considered. The results presented here are to be completed by a comprehensive analysis of the influence of species diversity and soil type on water and carbon exchange as well as on energy flows and canopy and soil microclimate.

Table 1. Water balance components during a dry 2006 growing season (May–Sept) in un-thinned and thinned stands.

	Un-thinned stand (mm)	Thinned stand (mm, % change)
Evapotranspiration	308	290 (-4%)
Transpiration	236*	218 (-10%)
Interception	38	29 (-25%)
Moss interception	12	16 (+30%)
Moss evaporation	16	20 (+25%)
Soil evaporation	15	21 (+25%)
Infiltration	158	163 (+3%)

* transpiration is partitioned as Scots pine 80%, undergrowth 4%, field layer vegetation 16%.

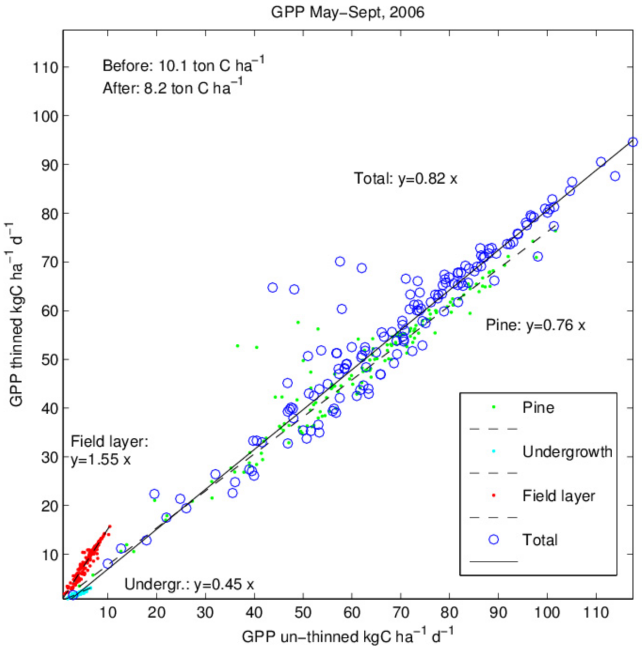

Figure 1. Daily Gross Primary Productivity (GPP) in thinned (one-sided LAI 2.0 m^{2}m^{-2}) versus un-thinned Scots pine stand (LAI 3.0 m^{2}m^{-2}) during a dry growing season of 2006 in Southern Finland. Removal of 1/3 of Scots pine and 2/3 of undergrowth leaf area reduces pine GPP by 24% while productivity of field layer vegetation more than doubles due improved light and water availability.

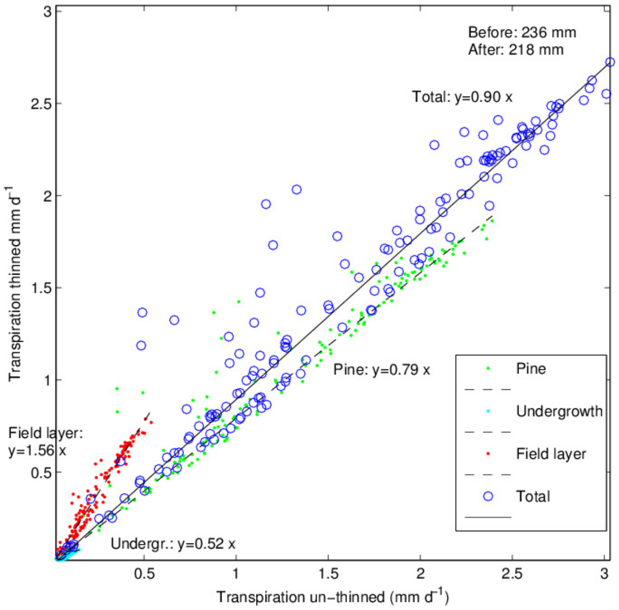

Figure 2. As Figure 1 but for transpiration.

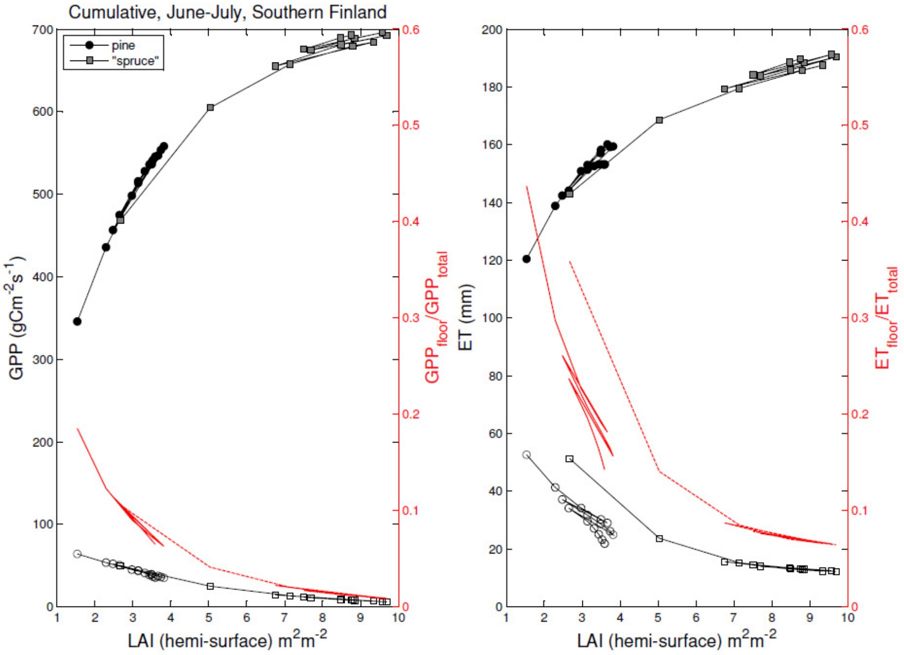

Figure 3. Total Gross Primary Productivity (GPP, left) and evapotranspiration (ET, right) as a function of stand one-sided leaf-area index (LAI). The upper curves show stand-level values while the open symbols at the bottom indicate lumped exchange of the bottom and field layers. On right vertical axis the forest floor contribution to stand-level values are shown. The lines connecting the points show how LAI changes due stand growth and thinnings.

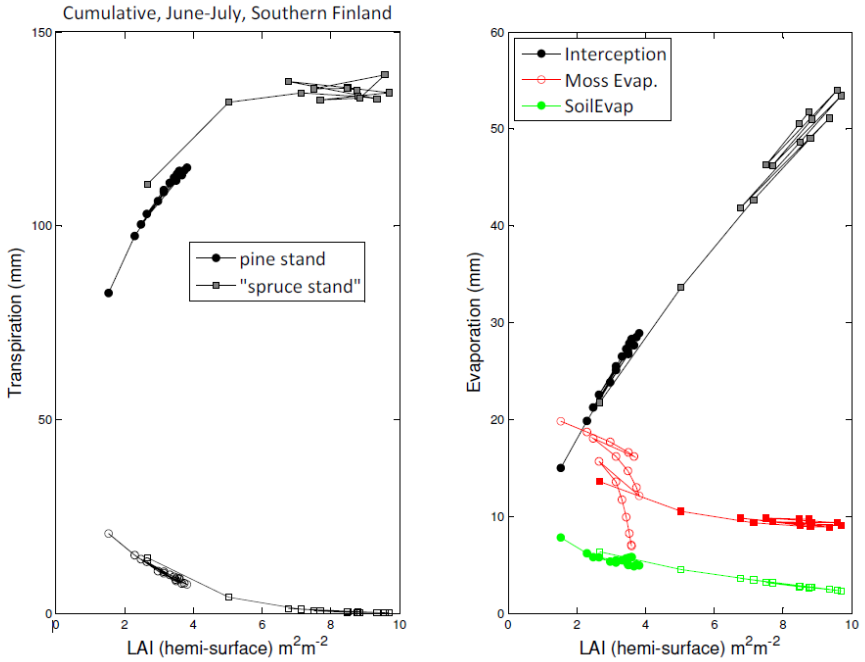

Figure 4. Cumulative transpiration (left) and evaporation components (right) as a function of stand leaf-area index (LAI). The upper curves show stand-level values while the lower ones indicate field layer transpiration (left) and moss & soil evaporation (right).

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Long-term effects of regeneration cutting and intensive biomass harvesting on nitrogen leaching to groundwater and surface waters

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Keywords: nitrate leaching, groundwater, long term monitoring, biomass harvesting, stumps.

The concentrations of nitrate and ammonium nitrogen in the groundwater were investigated one year before and 25 years after clear cutting and waste wood harvesting (1985) at the Pahalouhi experimental site at Kivesvaara, located in the northern boreal coniferous forest zone in Finland (64°28 'N, 27°33 'E). The effect of natural regeneration of Norway spruce *(Picea abies)* and Scots pine *(Pinus silvestris)* has been investigated at the same experimental site since 2002. All treatments caused a rise in nitrate nitrogen concentrations, but leaching during the first four years from natural regeneration was clearly less compared with clear cutting areas including waste wood harvesting and planting. Starting from close to zero, the concentrations of nitrate nitrogen continued to rise for 5-7 years, reaching 500-700 µg/1 at their highest, after which they began to decrease. The concentrations were still high twenty years after clear cutting. In natural regeneration reduction started after four years. Compared with nitrate, there was no corresponding leaching of ammonium nitrogen or other elements. In 2008 ground water monitoring was continued to evaluate nutrient leaching into the groundwater after stump uplifting. This new project has been implemented in three geographical areas from coastal area in southern Finland to northern boreal environment. Also in these sites clear-cutting and subsequent stump harvesting caused mainly nitrate leaching to the ground water. Nitrate concentrations started to increase in the following year (2009) of stump removal or other management practices. The maximum concentration, 8 mg/l, was reached in the third year (2011). In the seminar layout of the experiments and the importance of long term monitoring was discussed.

Session on ecosystem services

Stump harvesting. Photo Leena Finér.

The effects of stump harvest on soil surface disturbance, and carbon and nitrogen dynamics

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Keywords: stump harvesting, carbon, nitrogen, soil disturbance.

Introduction

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 Fennoscandia. Stump harvest, often combined with mounding, causes severe soil disturbance, such as mixing and relocation of the organic material and the mineral soil within the soil profile. Due to the lack of research, the possible environmental effects of stump extraction are uncertain and their time-scale unknown. The effects of stump harvesting on soil C and N pools, C and N mineralization, and soil surface disturbance were studied at three different clear-felled Norway spruce stands in Southern Finland. There are only a few studies addressing the long-term impacts of stump harvesting on C and N storage, C and N mineralization and CO_2 fluxes (Strömgren et al., 2012; i.e. Walmsley and Godbold, 2010).

Mechanized forest harvest often causes physical disturbance to the soil and the forest floor, and often results in patches of exposed mineral soil. Studies completed in the Nordic countries have found that stump harvesting can cause extensive (70–80%) exposure of the mineral soil in contrast to mounding (Kataja-aho et al., 2012).

The aim of this study was to determine how stump harvesting affects soil carbon and nitrogen dynamics, soil surface disturbance and soil compaction. We hypothesize that increased soil disturbance cauaed by stump harvesting could potentially result in c and n losses through mineralization. In addition, harvesting of tree stumps and site preparation could also lead to compaction at certain forest sites.

Material and methods

The study used a paired design, based on time since final felling and site fertility. Soil samples were systematically collected from the different soil surfaces found at stump harvest sites: mounds, excavation pits and the undisturbed surfaces. The extent of soil surface disturbance was visually estimated using a quadrat and a soil corer. Soil compaction was measured with a penetrometer, which estimates the that estimated the cone index (i.e. measures the resistance of the soil as a pressure unit).

Results

Preliminary results indicate that stump harvest can cause extensive soil surface disturbance in contrast to mounding. In addition, it appears that stump harvest can have an effect on the soil C and N pools thus our first findings are in agreement with previous studies done in Finland and Sweden.

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Growth responses of *Picea abies* seedlings after whole-tree harvesting and ash addition

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Keywords: biofuels, compensatory fertilization, crushed ash, Norway spruce, regeneration.

A new experimental series

In Sweden, the use of biofuels as an energy source has increased substantially during the last decades. Whole-tree harvesting (WTH) is, and ash recycling might become, large scale practices in operational forestry. There are few field experiments with ash addition in Sweden, especially when added in clear-cuts. In order to increase requested knowledge on how WTH and ash recycling affect growth of Norway spruce (*Picea abies* L. Karst), we test the following hypotheses in a new experimental series: (i) the growth is reduced after WTH by c. 10%, (ii) at fertile sites the growth is enhanced by ash addition, unaffected at medium-productive sites, and reduced at low-productive sites, (iii) the reduced growth by WTH is compensated for by ash addition at fertile sites only. The method include monitoring of survival and tree growth measurements in three field experiments located on sites of different fertility in the southern, middle and northern part of Sweden. The experiment in southern Sweden (291 Guvarp) was established in 2011. During the autumn 2014, the establishment of the one in northern Sweden (301 Granliden) will be finalized and the establishment of the one in the middle part (302 Galven) has started.

At all sites the following treatments are included: (i) conventional harvest of stems only (CH), (ii) whole-tree harvest (WTH), (iii) CH + 3 tonnes d.m. of self-hardened crushed biofuel ash (CH + 3KA), and (iv) WTH + 3KA. The amount of brash left in treatments (i) and (ii) was estimated by predictive functions at the respective site based on stand data of the stand before final felling and somewhat adjusted to correspond to the following relative amounts at the three sites: 100% (55 tonnes d.m. ha^{-1}) at 291 Guvarp, 75% (42.2 tonnes d.m. ha^{-1}) at 302 Galven and 50% (27.5 tonnes d.m. ha^{-1}) at 301 Granliden. In addition, at sites 301 and 302 an extra treatment was included named “CH additional”. In that treatment the same amount of brash (55 tonnes d.m. ha^{-1}) was left on the plots as in the CH treatment in the most southern experiment. The experimental plots are 20 m × 20 m in size and all assessments are made on the seedlings in net plots sized 15 m × 15 m. The seedlings were planted at a 2 m by 2 m spacing, giving a maximum of 64 seedlings per net plot.

Results from 291 Guvarp

At the oldest experiment, 291 Guvarp, survival and growth of the Norway spruce seedlings over the first three years have been assessed and evaluated by analyses of variance. Block (n = 5), treatment and seedling height at planting (covariate) were included in the statistical model, and differences among treatments were evaluated by Tukey’s test for multiple comparison. Some results are presented below.

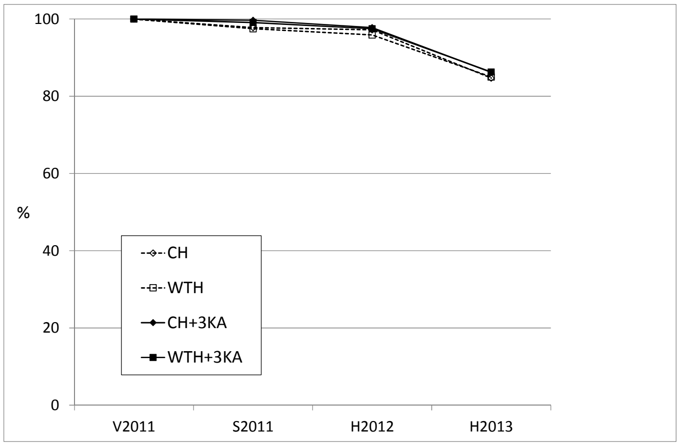

Figure 1. Survival of Norway spruce seedlings (n = 5) in the different treatments during the period 2011–2013 in experiment 291 Guvarp. The seedlings were planted in May 2011 (V2011) and the survival inspections were conducted in July 2011 (S2011), November 2012 (H2012) and September 2013 (H2013). For explanations of the treatments see text in section 1 above.

There were no detectable differences in survival rates among the tested treatments (Figure 1). On average for all treatments the survival was 86% in the autumn of 2013.

There were statistically significant ($p < 0.05$) differences among treatments for the total height of the seedlings in autumn 2013 (Figure 2). The mean height in treatment CH+3KA (98 cm) was significantly higher than both CH (87 cm) and WTH+3KA (89 cm), and those two treatments showed statistically higher mean values than WTH (74 cm). In relative terms, in relation to treatment CH (100%), the growth was reduced by 15% by WTH, unaffected by WTH+3KA, and increased by 13% in treatment CH+3KA. These results included fully vital and undamaged seedlings. Yet, the results were similar if all seedlings were included in the analyses (data not shown). Thus, the tree-year growth responses presented are in accordance with the hypotheses for brash removal and ash addition at fertile sites above (see section 1). However, these results only include the initial establishment of the seedlings for one of the experiments. All three experiments must be monitored for several decades in order to fully evaluate the postulated hypotheses.

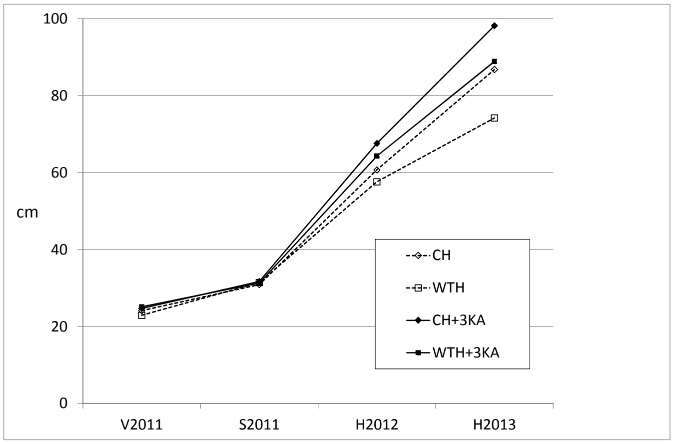

Figure 2. The height of Norway spruce seedlings (n = 5) in the different treatments during the period 2011–2013 in experiment 291 Guvarp. The seedlings were planted in May 2011 (V2011) and the growth measurements were conducted in July 2011 (S2011), November 2012 (H2012) and September 2013 (H2013). The data include fully vital and undamaged seedlings. For explanations of the treatments see text in section 1 above.

Climate change mitigation benefits of intensively managed and untouched forest

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Keywords: carbon emissions, forest carbon stocks, management intensity, bioenergy, fossil fuel substitution.

Recent research has concluded that forest biomass is not immediately a carbon neutral source of energy. It has been asserted that a time-delay exists between carbon being released in combustion, and carbon uptake by regrowth of plants. However, the length of the time-delay varies between studies. The aim of this study was to explore the climate change mitigation benefits of different forest management strategies, including untouched forest. The starting point for 100 year-long simulations was a mature, even-aged beech stand, that was regenerated according to three management alternatives: 1) leaving the stand, letting it develop into an untouched forest (UNT), 2) continuing the traditional management, which includes self-regeneration under a shelter of the old trees, with frequent thinnings throughout the stand's lifetime (BAU), and 3) conversion to short rotation poplar (BIO). We calculated forest carbon storage in living biomass and changes in dead wood and harvested wood product pools, in addition to net carbon emissions per area unit we also included substitution effects, assuming that the alternative fuel is bituminous coal. The average level of forest carbon stocks in living aboveground biomass was highest in UNT and lowest in BIO, with similar results for changes in carbon pools of deadwood and harvesting wood products. During the first 12 years, the annual net carbon emissions were lowest for UNT. After 12 years, BIO had the lowest carbon emissions. The net carbon emissions of BAU were lower than those of UNT after 30 years. Sensitivity analyses showed that these results were not sensitive to changed assumptions of 30% additional carbon stores in UNM, production and supply chain carbon losses of 38% (compared to 20% losses), changing wood heating values from 19.2 to 18 GJ tons^{-1}, or reducing production chain emissions for bituminous coal from 6% to 3%. When all these factors were considered together, BIO still had lower carbon emissions compared to UNM after only 19 years, while BAU was only more favourable than UNT after 67 years. However, using natural gas as a reference fuel may change the relative performance among the scenarios.

Ecosystem services in Swedish forests

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Keywords: ecosystem services, goods, forest, Swedish perspective.

A common concept for all goods and services is ecosystem services. For long, humans have tended to take these natural services for granted, but during the latest years, and mainly after the Millennium Assessment report (2005) and the TEEB report (2009), there have been attempts to identify, quantify, evaluate and economically price ecosystem services in order to put more focus on ecosystem values for human mankind to preserve them while time is. Work along the line of exploring the concept of ecosystem services are continuing and intensified worldwide. Governments have through the current years incorporated the concept of ecosystem services into targets and goals. Scientific literature on quantification and valuation of ecosystem services has literally exploded during the last decade (Tuvendal, 2012).

In Sweden, the government has concentrated its environmental work in a series of environmental objectives which needs to be reached within certain time frames (Swedish Environmental Protection Agency, 2012). During the latest years the concept of ecosystem services has been worked into Sweden's environmental objectives. The government also started a special investigation leading to further visibility of the value of ecosystem services in Sweden (SOU, 2013). The work led to a proposition during the spring of 2014 focusing on the development of political issues around ecosystem services.

Forests are life ensuring nature resources which create possibilities for biodiversity and health and prosperity for humans. In Sweden, forests cover approximately 50% of the land surface and as such are an important national land use category. The Swedish forests are rich in biodiversity, timber, berries and mushrooms, serve us with carbon sequestration and storage and supply the population with pure water and recreational opportunities. In this way, the Swedish forests are a central releaser of ecosystem services with large value for the population which makes the sustainability of these services important for all of the society.

In this paper we depict important ecosystem services in Swedish forests (Table 1). Through a literature study we identify, describe qualitatively, quantify and as far as possible economically valuate the most important ecosystem services in Swedish forests through focusing on appropriate indicators for each ecosystem service. Trade-offs between different ecosystem services in time and space are described and discussed. The objectives of this paper thus are to i) review data, and statistics on forest ecosystem services in forests based on Swedish, alternative Nordic literature, ii) identify the most important ecosystem services in Swedish forests along with possible indicators for these services, and to iii) study how these services are qualitatively described and quantified today and possibly can be further evaluated in the future.

Table 1. Ecosystem services observed in Swedish forests divided into the four main categories as specified in MEA (2005).

Ecosystem service group	Ecosystem service
Provisioning services	Timber, pulpwood and decorative materials
	Bioenergy
	Game
	Grazing animals and fodder
	Berries
	Mushrooms
	Drinking water
	Tree- or plant extracts with a medical or nutritious use
	Wood tar
	Recreational fishing in forest lakes
	Wooden crafts
Supporting services	Biogeochemical cycling
	Soil fertility; Soil quality
	Pollination
	Photosynthsis
	Habitats
	Biodiversity and genetic resources
	Resilience
	Distribution of pollen
Regulating services	Climate regulation and carbon sequestration
	Prevention of storm damages
	Prevention of erosion
	Water regulation – spring floods
	Regulation of pests and diseases
	Ensuring ground- and freshwater quality and quantity
	Clean air
Cultural services	Recreation and training activities
	Tourism
	Mental and physical health
	Aesthetics
	Knowledge and information
	Cultural and spiritual values
	Folk belief
	Inspiration for art and design

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Poster session

A clear-cut area. Photo Leena Finér.

Changes of nutrient concentrations in soil solution in the first year after different types of clearcutting

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Keywords: soil solution, nutrient concentration, whole tree harvesting, stem-only harvesting.

Wood biomass utilization for energy purposes is believed to increase substantially in the future. There are several ways to meet the increasing demand for energy wood; one of those is increased utilization of forest biomass. Intensified biomass harvesting potentially includes removal of branches, tree tops and stumps during clearcutting, thinning, drainage system renovation and other silvicultural activities. Stump removal is seldom practiced due to high costs and limited utilization possibilities, but extraction of logging residues has increased substantially during recent years.

According to calculations carried out in 2009, potentially available amount of logging residues from clearcuts in Latvia is 969 652 tons of dry mass per year, 62% of this amount is also technically available. More than half of available biofuel originates from clearcuts. However, there may be potential adverse effects: increased biomass harvesting may lead to leaching of nutrients from the forest ecosystem and possible decline of forest productivity in the future, as well as deterioration of water courses. More information on the effects of forest management methods on nutrient cycling and water quality is needed.

The research was carried out in two objects on mineral soils: *Myrtillosa* and *Hylocomiosa* site types. Three sampling plots were established in each object: whole tree harvesting (WTH), stem-only harvesting (SOH) and control (C). Tension lysimeters in 2 depths (30 and 60 cm) were installed in all sampling plots to collect soil water samples; water samples were collected twice per month during vegetation season in 2012 (reference period) and 2013 (first year after clearcutting). The average values of nutrient concentrations in soil solution between 2012 and 2013 were compared in each sample plot.

In *Myrtillosa* site type in WTH and SOH sample plots mean pH of soil solution in 2013 was lower than in 2012, the opposite is true for C plot of this object. In *Hylocomiosa* mean soil solution pH value has increased in WTH plot and decreased in SOH and C plot.

In 2013, average concentration of phosphates in *Myrtillosa* site type was lower than it was before harvesting, most notable changes appeared in C plot (Figure 2). A significant decrease of phosphate concentration was observed in *Myrtillosa* in C plot ($p = 0.009$) and in WTH plot ($p = 0.042$). No significant changes were detected in *Hylocomiosa*.

The most pronounced changes in total nitrogen concentration were observed in SOH plots of both site types (Figure 3). The mean nitrogen concentration in *Hylocomiosa* and *Myrtillosa* had increased from 1.4 mg L^{-1} to 3.17 mg L^{-1} and from 1.05 mg L^{-1} to 3.73 mg L^{-1} in SOH plots, respectively. Both objects show ignificant differences between years in all plots, except WTH (p-value for C plot in *Hylocomiosa* 0.044, in *Myrtillosa* 0.019; p-value for SOH plot in *Hylocomiosa* 0.012, in *Myrtillosa* 0.000).

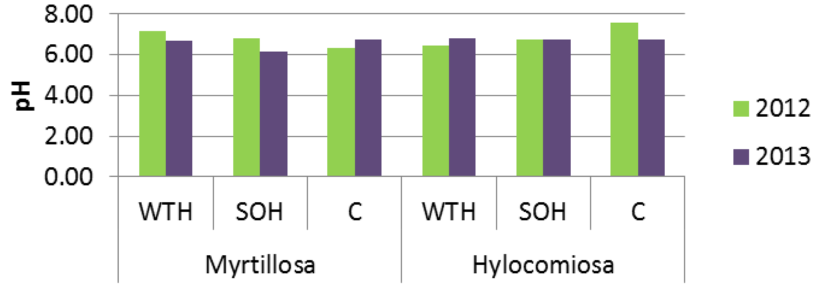

Figure 1. Mean pH values of soil solution.

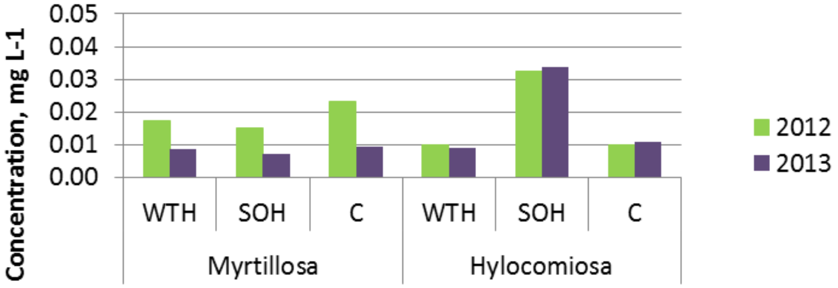

Figure 2. Mean concentration of phosphates.

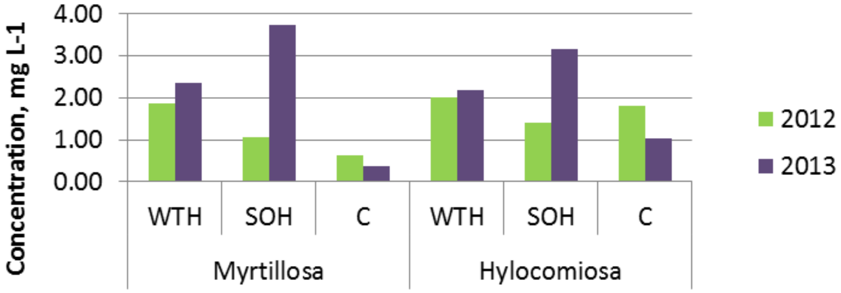

Figure 3. Mean concentration of total nitrogen.

Acknowledgement

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Long-term effect of site preparation on soil quality in Tuntsa, Finnish Lapland

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Keywords: Ca:Al ratio, Calcium, Magnesium, Mechanical site preparation, Norway spruce.

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

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

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

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

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

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

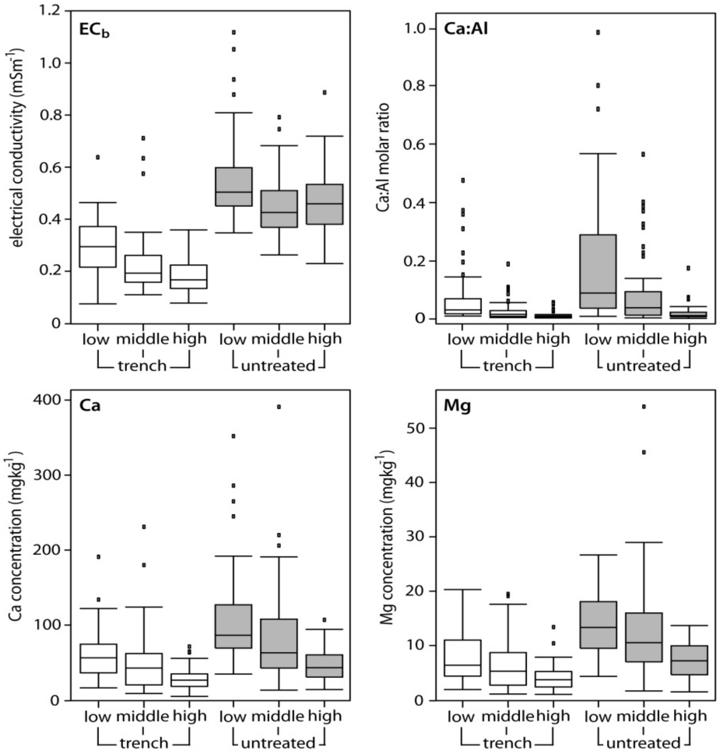

Figure 1. Boxplots to soil electrical conductivity (EC_b), Ca:Al ratio, and concentrations of Ca and Mg in low, middle, and high elevations of trench and untreated sites.

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Soil carbon stock change due to drainage of a forest stand growing on a transitional bog

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Forest drainage is a complex of engineering solutions increasing soil fertility, aeration and water regime. In Latvia it was common until beginning of 90ths to drain by ditching wet poorly aerated forest soils, as well as to regulate water regime to reduce of water erosion and flooding risk by changing location and flow capacity of natural streams. Forest drainage in Latvia is historically economy driven and it took place in conjunction with development of road infrastructure in forests. The drainage increase productivity of birch stands twice, pine stands – tree times and spruce stands – four times in compare to naturally wet conditions. Drainage of transitional bogs increase productivity 10 times (Zālītis, 2012).

The positive effect of drainage of forest productivity is result of aeration, decomposition of organics on peat and increase of stock of accessible nutrients from deeper soils layers. Considerable improvements of growth rate is found in all age groups, even 260 years old spruce stand may start to grow like the forest stand below final felling age. The increased increment rate remains even after deformation of drainage ditches; however, it drops down after final felling due to increase of groundwater level or negative impact of the machinery. The drainage is not efficient in lower bogs with dominating sphagnum peat, if the peat layer is deeper than 30 cm (Zālītis, 2012).

Vesetnieki research station was established in 1963. The total area of the research station is 370 ha, including 31% of forests on drained organic soil, which are located on a right bank of Veseta river in transitional bog. Forest drainage was done in 1960 (Zālītis, 2008). Initial depth of peat in transitional bog was 4.5 m. It consisted mostly of sedge peat (75–80 %) and woody peat (20–25 %). Down at 1.5–2 m depth reed peat was found. The sphagnum layer characteristic for transitional bog disappeared within 15 years. The decomposition rate of peat at 10 cm depth in 2008 was 55 %, in deeper layers 33% (Zālītis, 2008). Forest stands on drained organic soils corresponds to fertile stand types. An important part of measurements in the Vesetnieki research station was regular levelling out of the ground surface. Repeated measurements was done in 1966, 1970, 1975, 1977 and 1982. A part of the transitional bog was left untouched, providing opportunity to compare 2 scenarios of carbon stock change – natural and drained land.

The national greenhouse gas (GHG) inventory uses default emission factor for all drained organic soils – 0.68 tons C ha^{-1} annually. Total GHG emissions from drained organic soil in forest land according to the GHG inventory in 2012 was 1 069 Gg CO_2 and 124 Gg of CO_2 eq. of N_2O emissions. Organic soils in forest is one of the key source of emissions in land use land use change and forestry (LULUCF) sector (Latvian Environment, Geology and Meteorology Centre, 2014).

The scope of the study is to compare carbon stock changes in soil and other carbon pools after drainage of the transitional bog. The obtained data are supposed to be used in elaboration of the country specific factors of carbon stock changes in drained organic soil. Possible accumulation of carbon in peat in the untouched part of the transitional bog was ignored due to the fact, that visible height difference between land surface and tops of groundwater sampling wells was not found. Multiple data were collected in 30 sample plots, including stand characteristics, surface levelling, bulk density of soil and litter, carbon content in soil, litter and woody debris.

The surface levelling results demonstrated reduction of ground level by 25.7 cm during 51 year after drainage (Table 1), more significant reduction was found in spruce stands.

Table 1. Reduction of ground level after certain period of time (cm).

Dominant species	**7 years**	**12 years**	**14 years**	**19 years**	**51 years**
Norway spruce	11.8	11.5	15.9	13.9	28.6
Scots pine	-	13.7	15.6	6.8	21.4
Average	**11.8**	**12.0**	**15.8**	**11.8**	**25.7**

Carbon stock in living biomass in drained areas 51 year after drainage is 6 times higher than in transitional bog (Table 2). Carbon stock in dead wood and litter in drained plots is 34 times higher than in transitional bog (Table 3). Peat in drained plots in layers located above groundwater level is considerably more compacted than in natural bog and contains more carbon (Table 4).

Table 2. Carbon stock in different fraction of living biomass, tons ha^{-1}.

Growth conditions	**Dominant species**	**Stem**	**Green branches**	**Dry branches**	**Coarse roots**	**Small roots**	**Stump**	**Total**
Drained forest	Norway spruce	49.0	20.2	1.3	13.8	14.0	2.9	**101.3**
	Scots pine	60.3	10.2	1.5	8.9	9.0	1.9	**91.8**
	Average	**53.5**	**16.2**	**1.4**	**11.9**	**12.0**	**2.5**	**97.5**
Transitional bog	Norway spruce	3.8	8.5	0.1	1.5	1.5	1.0	**16.4**
	Scots pine	7.2	5.2	0.5	1.3	1.4	0.8	**16.4**
	Average	**6.1**	**6.3**	**0.4**	**1.4**	**1.4**	**0.9**	**16.4**

Table 3. Carbon stock in dead wood and litter, tons ha^{-1}.

Growth conditions	Dominant species	Litter	Coarse debris	Fine debris	Total
Drained forest	Norway spruce	4.5	4.8	1.6	10.9
	Scots pine	6.1	1.8	1.4	9.3
	Average	**5.1**	**3.6**	**1.5**	**10.2**
Transitional bog	Norway spruce	0.0	0.0	0.6	0.6
	Scots pine	0.0	0.0	0.2	0.2
	Average	**0.0**	**0.0**	**0.3**	**0.3**

Table 4. Carbon stock in soil at 0–80 cm depth, tons ha^{-1}.

Growth conditions	Dominant species	0–10 cm	10–20 cm	20–40 cm	40–80 cm	Total
Drained forest	Norway spruce	80.4	70.4	133.0	248.9	**537.0**
	Scots pine	65.5	63.1	116.9	226.0	**477.5**
	Average	**74.4**	**67.5**	**126.6**	**239.7**	**513.2**
Transitional bog	Norway spruce	35.3	31.7	61.0	174.6	**302.6**
	Scots pine	39.3	38.3	83.5	196.6	**357.6**
	Average	**38.0**	**36.1**	**76.0**	**189.3**	**339.3**

Carbon stock in soil increased significantly after drainage, even if upper 25.7 cm layer is considered to have zero carbon. The study results shows, that upper peat layers (down to 60 cm) are not decomposed, but compacted, when groundwater went down, and enriched with organic materials from forest floor. Total increase of carbon stock in the study area is 106 tons ha^{-1} (corresponding to removals of 7.6 tons CO_2 ha^{-1} annually). No significant difference was found in spruce and pine stands (Table 5).

Table 5. Corrected carbon stock changes in different carbon pools after drainage, tons ha^{-1}.

Dominant species	Living biomass	Dead wood	Litter	Soil	Total
Norway spruce	84.9	6.0	4.5	15.6	**110.9**
Scots pine	75.4	2.8	6.1	11.5	**95.7**
Average	**81.1**	**4.7**	**5.1**	**15.0**	**105.8**

The study demonstrates considerable overestimation of CO_2 emissions due to drainage of organic forest soil in Latvia (0.97 tons C ha^{-1} or 1 524 Gg CO_2 annually, if obtained results are applied to all drained organic soils). However, the study also highlights need to extend the study to obtain more comprehensive results representing different stand types and initial conditions. It is also important that the study evaluate only upper soils layer (55 cm in drained area); therefore, changes occurring in deeper peat layers should be evaluated further.

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