Belowground carbon turnover in European Forests

Laurent Augusto, Mark Ronald M. R. Bakker, Félix Bredoire, Anne Budynek-Gallet, Nathalie Gallegos, Karine Hakim, Sylvie Milin, Jérôme Ogée

Final conference COST Action FP0803

BELOWGROUND CARBON TURNOVER IN EUROPEAN FORESTS

13–15 May 2013
Luchey Halde, Bordeaux, France

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Final meeting of Cost FP0803

Local organizing committee
Laurent Augusto, Mark R Bakker (editor), Félix Brédoire, Anne Budynek-Gallet, Nathalie Gallegos, Karine Hakim, Nafissa Kerkoub, Jean Marmol, Sylvie Milin and Jérome Ogée

May 2013

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Global estimates of land photosynthesis inferred from the global budget of $\delta^{18}O$ in atmospheric CO_2: the crucial role of soil microorganisms

Jérôme Ogée[1] and Lisa Wingate[1]

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Abstract

Quantifying terrestrial carbon storage and predicting the sensitivity of ecosystems to climate change relies on our ability to obtain observational constraints on photosynthesis and respiration at large scales (ecosystem, regional and global). Photosynthesis (GPP), the largest CO_2 flux from the land surface, is currently estimated with considerable uncertainty (*1-3*). Robust estimates of global GPP can be obtained from an atmospheric budget of the oxygen isotopic composition ($\delta^{18}O$) of atmospheric CO_2, provided that we have a good knowledge of the $\delta^{18}O$ signatures of the terrestrial CO_2 fluxes (*1, 4*). The latter reflect the $\delta^{18}O$ of leaf and soil water pools because CO_2 exchanges "isotopically" with water [$CO_2 + H_2^{18}O \Leftrightarrow H_2O + CO^{18}O$]. This exchange can be accelerated by the enzyme carbonic anhydrase (CA). In leaves, where CA is present and abundant, this isotopic equilibrium is reached almost instantaneously. As a consequence, and because soil and leaf water pools have different $\delta^{18}O$ signatures, CO_2 fluxes from leaves and soils carry very distinct $\delta^{18}O$ signals and can thus be tracked from the fluctuations in the $\delta^{18}O$ of atmospheric CO_2 (δ_a). The accelerated isotopic exchange between CO_2 and water due to CA activity has recently been shown to be a widespread phenomenon in soils as well (*4*). Across a range of ecosystems, we found that CO_2 hydration was 10 to 1000 times faster than the un-catalysed rate, with highest values in the hottest ecosystems. At the global scale, accounting for soil CA activity dramatically shifts the influence of soil and leaf fluxes on δ_a, thus changing the estimates of terrestrial gross CO_2 fluxes. In this talk I will present the current state of understanding of the environmental and ecological causes behind the variability in CA activity observed in soils and illustrate how this variability can influence our estimates of global GPP inferred from δ_a budgets.

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Quantifying uncertainty in belowground carbon turnover

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Abstract

Uncertainty analysis is essential to scientific progress; it is needed for determining the significance of observed differences, for detecting trends over time and making predictions with known confidence, and for guiding research investments by identifying which components contribute the most to the overall uncertainty. In forested ecosystems, however, it can be very difficult to identify, evaluate, and propagate the many sources of uncertainty, and thus uncertainties have not traditionally been reported with estimates of ecosystem pools and fluxes. The difficulties are even greater belowground, where direct observations are not possible and many measurements are destructive.

In the case of soil measurements, a power analysis can be used to identify the magnitude of a difference that would be statistically significant given the intensity of sampling and the spatial variation in the sample. It is useful to report the magnitude of the difference that could have been detected, rather than to simply report that a change was not significant. A power analysis of forest floor studies in North America found that few designs were able to detect changes smaller than 20%; some were not sufficient to detect a doubling of forest floor carbon (Yanai et al. 2003). Sampling designs can be improved to allow detection of smaller changes while minimizing sampling and analytical effort.

In the case of root turnover estimated by minirhizotrons, there is subjectivity in the process of identifying roots in successive images, which adds to the more common sources of measurement uncertainty and natural variation. This process could be replicated by independent observers, to quantify this source of uncertainty. Other sources of uncertainty include biases due to the artificiality of the minirhizotron surface and the gap between the tube and the soil.

To estimate belowground carbon allocation from measurements of soil respiration and litterfall flux requires the assumption that soil storage of carbon is unchanged. The confidence interval around simplifying assumptions is rarely reported. However, if uncertainty in change over time is known (for example from the type of power analysis described above), this can be propagated through the estimate. In the case of ecosystem budgets in the northeastern USA, the estimates of change in soil pools are by far the largest source of uncertainty in net fluxes of carbon or nutrients (Yanai et al. 2012), due to high spatial variation. Non-destructive methods of estimating soil carbon would avoid this problem and thus may be able to better detect change over time (Wielopolski et al. 2010).

Quantifying Uncertainty in Ecosystem Studies (QUEST) is a Research Coordination Network recently funded by the National Science Foundation of the USA. The mission of QUEST is to support activities that advance the application of uncertainty analysis in five topic areas important to ecosystem studies: atmospheric deposition, stream water export, biomass, soils, and ecosystem budgets. QUEST has a website at http://www.quantifyinguncertainty.org, which includes sample code, links to papers, and news announcements. We will be developing discussion boards, wikis, and tutorials. Please join us if you have questions or suggestions for uncertainty analysis: quantifyinguncertainty@gmail.com.

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The "carbon cascade" into forest soils: mycorrhizal fungal role in a changing climate

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Abstract

Mycorrhizal fungi play a poorly circumscribed, but likely important, role in soil carbon (C) cycling. There are many factors that could regulate the flux of carbon to fungi, and the turnover of C once in the soil. These include host C flux belowground, proportional C allocation to fungi, turnover and C use efficiency of fungal tissues, and the chemical composition of these fungal tissues, all of which depend on biotic conditions, abiotic resources and conditions, and fungal community composition. In addition, some members of the mycorrhizal fungal community itself have at least limited saprotrophic capacity that can directly lead to C turnover, but also compete with free-living saprotrophs under certain circumstances, with potential for suppression of decomposition. Alternatively, root-mediated priming of decomposition has been identified in some settings. The role of mycorrhizal presence and type in inhibition vs. priming is poorly delineated. Climate change has many potential direct and indirect impacts on mycorrhizal fungal cycling of C. Changes in temperature have the potential to alter respiratory costs for mycorrhizal fungi, which will feed back to C use efficiency and tissue production. Likewise changes in water balance will have significant impacts on hyphal production, respiration, and turnover. Mycorrhizal fungal respiration is about an order of magnitude higher than that of roots, so the temperature dependence of respiration will have a large impact on the relative balance of C respired or incorporated in biomass. We have been tracking fungal respiration in lab and field studies, and growth in our Houghton Rhizotron Facility. We have found that the Q10 of ectomycorrhizal fungal respiration appears to decline as temperatures increase toward seasonal highs in temperate aspen forests. Fungal respiration and hyphal growth decline in response to seasonal drought. Community responses to persistent drought likely include increases in abundance of species with tissue chemistry and anatomy that enhance drought tolerance. These tissues are likely to be longer lived (e.g., more rhizomorphic) and may resist decomposition (more melanized, hydrophobic), so could lead to longer persistence of fungal tissues in soils. The identity of glomalin and its role in soil C stabilization are still debated. Future climate change will co-occur with other changes in atmospheric chemistry that could alter fungal communities and C allocation belowground, e.g., elevated CO_2 and N deposition. Understanding the interactions among these factors will require a mixture of experiments, gradient and longitudinal studies, and modeling.

Physical protection of soil organic matter: scales and questions

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Abstract

Organic matter is stabilized in soils for years to centuries or millennia because of its chemical recalcitrance, stabilization by interaction with the mineral matrix or physical stabilization. Physical protection or physical stabilization of soil organic matter comes from the limited access that microbial decomposers have to organic substrates, water and oxygen in the complex three dimensional architecture of soils. Physical protection is though to be a major process at temporal scales from decades to centuries.

Much work has been performed on this process, usually based on the physical fractionation of soil aggregates of different sizes and stabilities and of their associated organic matter. Its importance has been demonstrated in soils under various land uses. Here we focus on what we perceive as standing questions regarding this stabilization process:

- What are the spatial scalesof physical protection?
- Which approach should be preferred: the aggregate-based approach or a pore system-based approach?
- What is the relative importance of physical protection and physico-chemical protection? Physicochemical protection results from the adsorption of organic matter to minerals.
- How to model physical protection?

To address these questions we will use results obtained on soils from long term experiments as well as from microcosms experiments.

Including ectomycorrhiza in ecosystem models - effects on simulated C and N fluxes of forests

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Abstract

It has long been acknowledged that Ectomycorrhiza have a major impact on forest C and N cycles. Nevertheless the are only rarely considered explicitly in complex ecosystem models. By that, the dynamic effect of ectomycorrhizal fungi growth on plant andsoil C and N cycling is neglected. The reason for the scarcity of model attempts can partly be explained by the huge variety in fungal species and their differences in appearance and functions which hamper model development. In order to fill this gap, the ectomycorrhiza feedback model MYCOFON was developed which allows the simulation of the C and N exchange between a mycorrhized root and the fungus via the fungal hyphal mantle. In order to fully test the model, MYCOFON was linked to the complex ecosystem model COUP. Model runs were compared between the linked MYCOFON-COUP set-up and the original COUP which contains mycorrhiza implicitly. A Bayesian calibration was performed which allows quantifying the respective model precision as well the uncertainty of model parameters for both model approaches. It could be demonstrated, that including ectomycorrhiza explicitly in COUP had considerable effects on the simulated soil C and storage as well as on the uncertainty of model parameters. For future model development, more information on fungal parameters settings as well fungal processes is necessary to narrow these uncertainties.

Soil carbon models used for Kyoto Protocol reporting

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Abstract

Soil carbon represents the largest carbon pool of terrestrial ecosystems. Globally, the amount of carbon contained in soils is approximately twice as large as that contained in the atmosphere (Rustad et al., 2000). Thus, it is crucial to understand the factors regulating soil carbon dynamics and the impacts of climate and land use change on the terrestrial carbon cycling.

Soil carbon reporting under the Kyoto protocol falls under the category Land Use, Land-Use Change and Forestry (LULUCF), defined in articles 3.3 and 3.4 (optional). Article 3.3 includes only those land areas where afforestation, reforestation or deforestation took place in the reporting period. Other activities such as forest management are contained in article 3.4.

The Intergovernmental Panel on Climate Change (IPCC) defines guidelines for quantifying yearly change in soil carbon stock. It recognizes methods of 3 levels of complexity: Tier 1, Tier 2, and Tier 3. The use of mathematical models falls under the most complex Tier 3 method. Mathematical models are tools to increase our understanding of the underlying mechanisms of soil carbon cycling. They also facilitate predictions of the impact of climate or land use change on soil carbon sequestration.

At the COST FP0803 Workshop that took place on 9-13 July 2012 in Vienna, Austria, we investigated which of the Annex I countries used mathematical models for their soil carbon reporting in the national inventory reports of the year 2012. We did not distinguish for which land use change category the model was used but only recorded whether a model was used at all and which model it was. The resulting list is shown in Table 1.

Table 1 Mathematical models used for soil carbon reporting by Annex I countries in 2012
(http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/6598.php)

Model	#	countries
Yasso/Yasso07	5	Austria, Finnland, Norway, Slovenia, Switzerland
Century	3	Canada, Japan, USA
Roth C	2	Australia, Russia
C-Tool	1	Denmark
Introductory Carbon Balance Model	1	Sweden
Dynamic Carbon Flow Model	1	UK

Out of 43 Annex I countries, 13 countries used or planned to use a mathematical model for soil carbon reporting. Three European countries, i.e., Denmark, Sweden and UK, based their reports on their own national models while ten countries used publicly available established soil carbon models. The Rothamsted Soil Carbon Model (Roth C, Coleman and Jenkinson, 1996) was used by Australia and Russia, the Century model (Parton et al. 1992) was used by Canada, Japan and USA. Remaining countries using models, Austria, Finnland, Norway, Slovenia, Switzerland, used the model Yasso/Yasso07 (Tuomi et al. 2011). Thus, Yasso/Yasso07 is the most widely used mathematical model for soil carbon reporting by European countries. Other soil carbon models that have not been used for reporting so far include ROMUL (Chertov et al., 2001) and SOILN (Eckersten et al., 1998).

All soil carbon models are dynamic and consider several carbon pools in the soil. Yasso/Yasso07 and Roth C are relatively simpler than the Century model that also has a spatial component.

In this talk, I will discuss and compare Yasso/Yasso07, Roth C and Century in more detail, in particular with regard to the core mathematical model, and the model inputs and outputs.

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7th Abstract oral Etienne Mathias

The Abstract for this talk did not reach us in time when the document was sent to the printing company. We intend to upload this to the electronic version that can be downloaded from the COST FP0803 website shortly after the conference.

The uncertainty of modelled soil carbon stock change for Finland

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Abstract

Countries should report soil carbon stock changes of forests for Kyoto Protocol. Under Kyoto Protocol one can omit reporting of a carbon pool by verifying that the pool is not a source of carbon, which is especially tempting for the soil carbon pool.

The Yasso07 (Tuomi et al. 2011) and Romul (Chertov et al. 2001) soil carbon models were tested against repeated soil carbon inventory (Biosoil) in Finland resulting that mineral soils were sinks of carbon between 1986–2006, but noting substantial uncertainties with models and measurements (Rantakari et al. 2012). Also Ortiz et al. (2013) tested soil models Yasso07 and Q against repeated soil carbon inventory of Sweden. They concluded that according to the measurements soils were most likely a small sink of carbon between 1994–2000, but both models predicted close to zero values for carbon stock change. These studies imply that verification that soils of a nation are not a source of carbon in given year seems to be nearly impossible. Here we wanted to quantify the uncertainty soil of carbon stock change for mineral soils in Finland.

The Yasso07 model was parametrized against various decomposition data using MCMC method. Soil carbon change in Finland between 1972 and 2011 were simulated with Yasso07 model using litter input data derived from the National Forest Inventory (NFI) and fellings time series.
The uncertainties of biomass models, litter turnover rates, NFI sampling and Yasso07 model were propagated with Monte Carlo simulations. Due to biomass estimation methods, uncertainties of various litter input sources (e.g. living trees, natural mortality and fellings) correlate strongly between each other. We show how original covariance matrices can be analytically combined and the amount of simulated components reduces greatly.

While doing simulations we found that proper handling correlations may be even more essential than accurate estimates of standard errors. As a preliminary results, from the analysis we found that both Southern- and Northern Finland were soil carbon sinks, coefficient of variations (CV) varying 10%–25% when model was driven with long term constant weather data. When we applied annual weather data, soils were both sinks and sources of carbon and CVs varied from 10%–90%. This implies that verification of soil carbon sinks depend on weather data applied with models. Due to this fact IPCC should provide clear guidance for the weather data applied with soil carbon models and also for soil carbon sink verification. In the UNFCCC reporting carbon sinks of forest biomass have been typically averaged for five years – similar period for soil model weather data would be logical.

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Problems arising from calculation and reporting of organic carbon stocks in soil: Romanian cases

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Abstract

Romania has a great variety of lands and soils, but also a good soil database: 5.000 profiles of soils resulted from the management activity of forests, 240 from European Monitoring systems and 2.665 from the National Forest Inventory.

In my talk I will specifcially address the following problems occuring in Romania:

1. How to calculate the organic C stock in soil: starting from the same data (2700 profiles of soil) I have made calculations in 3 different ways: on pedogenetical horizons, on standard depths and, finally, through the usage of the regression equation. Significant differences exist between these methods, but the second one is considered to be the most appropriate and efficient.
2. At what depth the organic C stock in soil must be calculated: 100 cm, except for the thin soils (e.g. rendzic leptosol=50 cm).
3. Forest land remaining forest land: the soil samples must be taken in the same places at an interval of 10 years difference (what if the drought is high in that year?).
4. Land converted to forest land: Project realized in 2003 and financed by Prototype Carbon Fund (PCF) and the International Construction and Development Bank – afforestation of 6.033 ha with black locust, willow, poplar and greyish oak. The soil samples were harvested in 2003 and 2013, and a slight growth difference of organic C was observed. However, the area is small, being situated in the plain area, so that the problem of C sequestration was resolved only for 4 forest species. Other studies with other types of forest species will follow in the hill and mountain areas.
5. Dead organic matter: no data available, great variability, hope for future data.

Poster Abstracts

in alphabetical order of <u>presenting author</u>

Modeling soil organic carbon of Scots pine stands in Lithuania

Jūratė ALEINIKOVIENĖ[1], Kęstutis ARMOLAITIS[1], Vaiva KAZANAVIČIŪTĖ[1], Ari LAUREN[2], Dovilė ČIULDIENĖ[1]

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Abstract

Forests take the most important role in carbon sequestration in terrestrial ecosystems along the accumulation of carbon in stand biomass, thus, organic carbon is increasing in mineral soil due to accumulation of forest litterfall in forest stands. However, climate changes may affect the carbon exchange in forest soils. In this study, the soil organic carbon (SOC) stocks in Lithuania have been evaluated under consistent climate and under two climate change scenarios according to Kelemen et al. (2009). The chosen scenarios for changing climate in Northern Europe at 2090–2099 have been characterized as: A2 – pessimistic scenario (the temperature at global scale will rise from 2.5º to 4.5ºC), and B2 – optimistic scenario (the global scale temperature will rise from 1.5º to 3.0ºC).

The FEMMA model (Laurén et al., 2005) was applied for the research on the SOC stocks modeling for the period 2010-2011 in Scots pine (*Pinus sylvestris* L.) stands on *Arenosols*. The model was adapted by Lithuanian (consistent) daily climate data and simulated with increased seasonal (winter and summer) temperatures by 5ºC (A2 scenario) and by 1ºC (B2 scenario). In the model the gross primary production (GPP), total ecosystem respiration (TER) and net ecosystem exchange (NEE) under the changing temperature were the most important contributors for the estimation of SOC stocks.

It was calculated that under optimistic B2 climate change scenario no significant changes on estimated parameters of Scots pine stands could occur. However, under pessimistic A2 scenario the GPP could increase not significantly whereas with significant consequence of TER increase and NEE decrease. Thus, the decrease in stocks of SOC from 39.6±2.9 to 32.9±3.5 t ha^{-1} in the mineral soil (0–100 cm depth) of Scots pine stands could be relevant in response to significant increase in TER, both, under consistent climate and under A2 scenario. Therefore, taking into the account that the CO_2 will accumulates as the GPP, Scots pine stands in Lithuania could neutralize approximately 25% of total greenhouse gas emissions (i.e. 22000 Gg CO_2).

Key-words: Lithuania, climate change, FEMMA model, Scots pine stands, *Arenosols*, soil organic carbon.

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Mycorrhizal hyphae contribution to C-dynamics in forest soils

Frida Andreasson[1], Masako Dannoura[1], Yuji Kominami[2], Naoki Makita[3] and Mioko Ataka[3]

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Abstract

In forest ecosystems, CO_2 flux from the soil to the atmosphere is a combination of respiration from roots, mycorrhiza and root associated microbes (autotrophic respiration) as well as free-living soil microbes and animals that get carbon from decomposition of plant debris (heterotrophic respiration). This challenges us researchers to separate these fluxes for a better understanding of the C-dynamics of the forest.

We aim to study the activity and production of external mycorrhizal hyphae and the relationships between the two processes as well as seasonal variations.

This study was carried out in a mixed temperate forest dominated by ectomycorrhizal forming *Quercus serrata* located in Kyoto, Japan.

In March 2011, nylon mesh bags (64 cm², pore size 41 μm and 1 μm) filled with 60g dry sterile granite soil were installed in the top 5 cm of soil profile. The 41 μm bags allow ingrowth of fungal hyphae but exclude fine roots thus representing activity and production of hyphae and bacteria while 1 μm bags exclude also ingrowth of fungal hyphae, thus showing only activity and production of bacteria. The low carbon content of the soil in the bag will exclude saprophytic fungi to enter the sample. Bags were collected every second to third month until September 2012. Direct after sampling the CO_2 fluxes from soil inside the bags were measured with an infrared gas analyzer (GMP343, Vaisala, Finland). Samples where then transported to lab for biomass analyses.

Our preliminary results show a higher respiration rate per bag from 41 μm than from 1 μm pore sized ingrowth bags and Respiration/Biomass indicates a rapid mycorrhizal hyphae turnover.

A simplified method of root observation through picture sampling in rhizotrons: choosing how much and how often

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Abstract

A simplified sampling method to estimate root production from pictures taken regularly from a rizotron is presented. Pictures were taken fortnightly from the visible side of several rhizotron modules in which a series of vine plants were growing. A single picture of each module was taken with a reflex camera from a distance of about 2.3m, with a focal length of about 45mm to obtain a non-distorted image. Images were processed with GIMP software to cut the images at specific markers and forced to a specific size (2000 x 9000 pixels) in order to make successive pictures of each single root directly comparable. A grid was also added to each image with squares of 400 x 400 pixels, to allow identification and subsampling. Three depth ranges were studied separately: 0–30cm, 30–60cm 60cm – bottom (total module depth 1.05cm aprox.). In each depth range, five squares were randomly selected to be followed along the time. In each square, roots were redrawn with a different colored line according the following: all roots having a color from white to clear brown considered new, dark brown roots were considered completely lignified and roots having intermediate colors were considered lignifiying roots; roots disappearing from one picture received another set of colors. This way, total length of each root class could be measured in each square with Winrhizo software. Then, root production for each root class could be calculated from the combination of present roots, disappeared roots, and roots present the previous date, assuming that two consecutive pictures being separated only two weeks, any root could only pass from one class to the next one. For instance, for lignified roots $L_n=L_{n-1}-DL_n+PL_n$, where L_n is the total length of lignified roots of date n, L_{n-1} same for date n-1, DL stands for roots disappeared from date n-1 to date n, and PL stands for roots "passing" to lignified class from lignifying class. This last term is the only one not directly measured but calculated and is used for the calculations of the other classes. Then, a modified boot-strap method was used to determine the minimum number of squares to be processed for mean stability and a certain level of error: we applied a resampling technique that created mean values for a variable number of squares form one to five, which allowed us to relate the mean, 90 and 95% confidence limits of the obtained distribution with the number of squares and compared them with accepted errors around the total mean obtained with all five squares. The results were similar at all depth ranges, varying from one for 5% error at 0–30 and 30–60 cm to 3 for 2% error at 60 to bottom range, were the lower number of roots resulted in larger heterogeneity.

Comparison of ingrowth bags and ingrowth meshes in root studies: 3 years of data on *Pinus pinaster* and its understory

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Abstract

Assessing root production and turnover of carbon and or nutrients through roots is still a challenging task, yet primordial to reach full understanding of biogeochemical cycles in many ecosystems. In recent years ingrowth meshes have been proposed as a further tool to study root production and turnover, next to more classical methods as sequential coring, ingrowth bags or minirhizotron methods.

In this study, we applied flexible mesh material (6 mm mesh size) in *Pinus pinaster* production forests in southwestern France, featuring the following 5 dominant understory species: *Cytisus scoparius*, *Calluna vulgaris*, *Erica cinerea*, *Pteridium aquilinium* and *Molinia caerulea*. Four stands for each combination of dominant understory and *Pinus* were investigated throughout the study. The mesh material was either applied as bags (8 cm diameter, 15 cm deep, filled with soil from each site, topped with a litter lid) or as 50 cm long meshes (put with spades down to 15 cm in the soil, topped with litter). Harvests were carried out after 9, 24 and 36 months. For each sample roots were separated according to species, diameter class ((<0.5, 0.5–1, 1–2, 2–5, 5–10, 10–20 and 20–50 mm) and vitality (live or dead). Measured or derived root parameters considered include number of roots (mesh only), fine root biomass, fine root length, fine root density, specific root length, branching (number of apices per m of root length, for *Pinus* only), live fraction and for fine roots percentage of roots in a given diameter class (relative to all roots <2 mm). In order to compute these parameters for the meshes we considered a hypothetical volume of 2.5 cm on either side of the mesh times 50 cm length and 15 cm height. We expected i) that the ingrowth mesh method would be more suitable in monitoring growth (i.e. production and turnover) of coarser root diameters as a larger mesh surface was available for roots to grow through relative to the bags. Furher, we hoped ii) that meshes would cost less time for root extraction.

Results show for most understory – *Pinus* combinations a higher fine root biomass for understory species than for *Pinus* (with the exception of *Cytisus*), but patterns for fine root biomass over time (9 to 36 months) were similar for understory and pine: increase from 9 to 24 months, then a decrease. Meanwhile, between 24 and 36 months the live fraction decreased (between 90 and 100 % after 24 resp. 9 months, down to 40–60% after 36 months). Total root biomass (live + dead roots) present in both bags and meshes was actually higher after 36 months. Patterns for fine root length and fine root length density were similar to the pattern for fine root biomass. When comparing bags with meshes there seems to be less biomass growing into meshes than into bags for the finest root class (<0.5 mm in diameter). But when considering all fine roots (<2 mm) this is not evident, suggesting that more roots of the coarser fine root classes (0.5-1.0 and 1–2 mm) classes dominate in the meshes. This might point to some delay of soil exploitation of the mesh zone by roots (fewer very fine roots, larger proportion of less fine roots). Specific root lengths, indeed, were rather similar for pine roots in bags and meshes for the <0.5 mm class, but lower in meshes for the <2mm class than in bags. Presumably, the disturbance in mesh zones (upon installation) is higher than for bags: e.g. small roots (2–5, 5–10 or sometimes bigger roots) were found damaged on the outside of the mesh zone, giving rise to many reiterated roots of smaller diameter (1–2, 2–5 mm). This would suggest some bias to the numbers (and properties) of roots of the coarser diameters.

The overall conclusions are:
1. Ingrowth bags and meshes give roughly comparable results
2. Observed differences may be size related (larger volume for colonization, more disturbance potentially). In particular, the method did not, in our case, yield enough exploitable results for small to coarse roots (2 to 50 mm in diameter) and therefore, we cannot conclude that ingrowth meshes are clearly a better method for studying small and coarse roots.
3. Handling ingrowth meshes did not cost less time than handling ingrowth bags in our study.
4. We suggest using smaller mesh surfaces (20 cm?) and of more rigid material to optimize the mesh method as an alternative to ingrowth bags.

Fungal communities in topsoil reflect dominant vegetation while bacterial communities respond to soil chemistry

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Abstract

The composition of soil microbial communities reflects both soil physicochemical properties and vegetation traits mediated by the rhizosphere and litter quality. This study compared the relative importance of the above factors on the composition and function of bacterial and fungal communities that were previously documented to affect soil chemistry and function (Šnajdr et al. 2013). The study considered tens of temperate soils with contrasting physico-chemical properties and a set of 24 soils with similar initial composition, planted with six tree species. Microbial communities were characterised by pyrosequencing, qPCR, and enzyme activity measurements. Soil properties and vegetation affected the bacterial and fungal community differently. While pH and C/N ratio were most important for bacterial community composition, fungal communities were highly vegetation-dependent and showed low response to other soil factors. Among dominant taxa, only 6% of fungi but 25% of bacteria were shared in similar soils under all six trees while 33% fungi (and 12% bacteria) were specific for single tree species. Soil pH had major effects on enzyme activity and microbes were found to produce enzymes fitting their environment, with catalytic optima reflecting pH of respective soils. Soil fungal communities are largely vegetation-dependent while bacteria and microbial processes are mainly influenced by other soil properties.

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Effects of soil preparation and regeneration on *Pinus sylvestris* root development

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Abstract

The main factors affecting the root biomass and distribution of forest trees are age and tree species, water supply, soil fertility, carbon allocation, abiotic factors such as soil temperature, soil density, aeration and even the level of toxicity. The objective of this study was to determine the effect of soil preparation and regeneration on *Pinus sylvestris* L. root development. The study tasks were to compare amount of root biomass and development between naturally regenerated stands with planted stands were soil preparation was done (artificial stands).

The research was carried out in sapling *Pinus sylvestris* L., naturally regenerated stands and artificial stands. The study area was located in Zemgales flat land forests of Latvia. The stands represent different age of development – 24-year-old and 45 year old. The site type in both stands according to Latvian classification is *Hylocomiosa*. One experimental plot of 500 m^2 was established in each stand in 2012. The diameter (1.3 m above-ground level) distribution of all trees of the sample plots was determined. Trees were selected for excavation using a systematic random technique. We selected only healthy, undamaged trees within the diameter range (one minimal, three averages and one maximal sample tree per each plot) and with average tree height. The total root system of 20 sample trees (5 in each sample plot) was excavated, washed, divided into diameter classes (small roots – $2 > \emptyset < 20$ mm, coarse roots – $\emptyset > 20$ mm), weighed and estimated root distribution in different soil layers. Twenty soil cores (volumetric samples 100 cm^3, core diameter 50 mm) were systematically taken for fine root biomass determinations in each sample plot.

The amount of fine root biomass varied both between the experimental designs and between soil layers. The major part of the fine roots was found in the upper mineral soil 0 – 10 cm, 46% in naturally regenerated stands and 55% in artificial stands. Soil preparation and regeneration aspects significantly affected ($p < 0.05$) small and coarse root development. In artificial stands roots produce more biomass and contribute to the development than naturally regenerated stands. Artificial stands provide improved root systems vitality and better conditions for roots developing and living.

Effects of stabilisation on soil organic matter porosity in cemented podzolic horizons

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Organic matter (OM) occurs in soils in various pools showing different resistance degrees against degradation as a consequence of the mechanisms governing their stabilization. In Podzols, OM is mainly stabilised by association with the mineral phase, and with the ongoing of podzolisation an enhancement of metal-organic interactions (Fe- and Al-OM) occurs. Although OM typically has a very complex structure, in which the abundant microporosity may reach dimensions even <2 nm, when stabilized by mineral associations OM structure can change. A larger ultramicroporosity (<0.7 nm) than the labile pool is expected, reflecting the higher rigidity/condensation of OM structure given by association with metals. In well-developed Podzols, a metal-rich cemented horizon, called ortstein (Bsm or Bhsm), may form in addition to non-cemented Bs or Bhs ones. In these cemented horizons OM ultramicroporosity may be enhanced. To investigate OM structure the gas adsorption technique is particularly suitable: thanks to the different accessibility of N_2 (77K) and CO_2 (273K), the pores between $\sim$<2 and 50 nm and down to less than 0.5 nm respectively can be characterized. In this work we evaluated the features of metal-organic associations in podzolic cemented horizons in term of surface properties and compared them with those of the more labile OM pools. Three Podzols were selected in NW Italy, and both the Bs or/and Bhs and cemented horizons were sampled. The samples were treated with 6% NaClO at pH 8 to eliminate labile OM, and the specific surface area (SSA) was evaluated before and after oxidation (UT and T samples, respectively) with both N_2 and CO_2. The N_2 detectable SSA seemed to be strongly affected by the porosity of the mineral phase, but the variation of SSA upon oxidation was linked to the horizon type. Only the Bs/Bhs horizons showed the typical increase in SSA after the removal of labile OM, while in the cemented horizon the SSA decreased. This probably reflects the exposure of highly stabilised OM, richer in ultramicroporosity, in the ortsteins. Conversely, the SSA measured by CO_2 was mainly affected by the presence of OM in both UT and T samples (r^2=0.973 and 0.918, respectively). The two functions showed equivalent intercept values (4.35 and 4.36 m^2g^{-1}, respectively), indicating that oxidation had no effect on the contribution of the mineral phase on micropore surface. The slopes instead were different, and indicated that stabilised OM increased the SSA twice as much as the UT sample. Our results show a sharp variation in OM structure upon stabilisation, with a larger portion of CO_2 accessible surface in stabilised OM.

Disease in trees reduces the C allocation to fine roots

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Abstract

Knowledge about carbon (C) allocation among tree organs with different life times and decomposition rates is crucial in determining the residence time of carbon (C) in forests. Maintenance and growth of tree organs i.e. fine roots, coarse roots, stems, and branches, are controlled by phenology, environment, but also by the vitality of the trees. The health status of the trees influences the C fluxes allocated annually to assimilation, respiration and biomass production. We know little about how diseases in trees influence the C allocation in trees and below ground.

The aim of our study was to estimate how the health status of the trees influences the fine root biomass.

We selected two experimental stands (Sande and Hoxmark in SE Norway) with about 40–50 years old Norway spruce (*Picea abies)* with scattered trees having typical top-dieback symptoms. The symptomatic trees had dry crown tops, short top shoots, needle yellowing and thinning of crowns, while non-symptomatic trees looked healthy. We sampled the the fine root biomass by soil coring to 25 cm depth, 1 m from boles of trees either with typical top dieback symptoms or non-symptomatic ones. Fine roots < 2mm in diameter were picked out and their biomass was estimated.

The fine root biomass differences were largest in the O-soil horizon, where most of the spruce fine roots were located. In O-horizon the fine root biomass in symptomatic trees decreased to ¼ and ½ compared to non-symptomatic trees in Sande and Hoxmark, respectively. At the same time, the fine root necromass in symptomatic trees almost doubled compared to non-symptomatic trees in both stands.

In conclusion, we show that the health condition of trees has a significant influence on the allocation of C to fine roots and to litter in the forest soil. Thus, the pool of fast decomposing C (e.g. fine roots) will differ according to the health condition of the forest stand.

Interconnection between carbon and nutrient cycling in fragile forest ecosystems

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Abstract

Temperate broad-leaved semi-natural forests of central European plains are of great natural, cultural and landscape value. However, they are frequently restricted to relict spots in poorly fertile areas. In these fragile ecosystems element biogeochemistry and nutrient supply are tightly connected to soil organic matter (SOM) decomposition and C turnover. Disturbances, such as the introduction of alien species, may easily disrupt the fragile equilibrium and rapidly lead the ecosystem to nutrient limitation. In this work we evaluated the effect of American red oak (*Quercus rubra* L.) introduction in a broad-leaved semi-natural forest in NW Italy (*Quercus*, *Tilia*, *Acer*, *Fraxinus* and *Ulmus* spp.) on SOM dynamics while assessing the consequent effect on nutrient cycling and bioavailability. We selected two adjacent sites covered by red oak plantation for 80 years (RO) and semi-natural broad-leaved forest (NF). Both sites have the same soil type (Typic Fragiudalfs) characterized by the presence of a fragipan horizon (60–80 cm) which causes periodical hydromorphic conditions and limits root penetration. SOM dynamics were evaluated by determining decomposition rate, and distribution between labile and recalcitrant pools. Total and available contents of major nutrients (N, P, K, Ca, and Mg) were also determined. The first effect of RO invasion was a change in the humus type from *Hemimoder* (Oi-Oe/A horizons) to *Humimor* type (Oi-Oe-Oa horizons) and an increase in organic C particularly in the episolum (from 6.0 to 14 kg C m^{-2}). Humus composition did not show significant differences in the distribution between labile and recalcitrant forms. However the Oe and Oa material in RO showed a reduced rate of decomposition after 15 days of incubation compared to Oe and A horizons in NF. We speculate that the accumulation of organic matter in RO could be due to the presence of allelopathic compounds, such as condensed tannins, which inhibit microbial activity rather than to a greater abundance of recalcitrant components. As a consequence, extensive immobilization of N, P, Ca, Mg and K was observed in the humus layer leading to a considerable depletion in deeper horizons. In particular, the dramatic reduction in available P and Ca in the E and Bt horizons results in nutrient limited forest ecosystems that preferentially select for plant species with low nutrient requirements. We show that the invasiveness of red oak in the area could be explained by modifications in carbon and nutrient cycling, which lead to unfavorable conditions for re-colonization by autochthonous species.

Correlation between the flow CO$_2$ from soil and selected parameters of root-soil system

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Abstract

The research on the effects of root biomass, ergosterol content in roots and soil, C/N, pH, carbon content and other root and soil parameters on CO$_2$ flux from soil has been carried out in the Rajec nad Svitavou-Němčice in Drahanská vrchovina (highlands) in the Czech Republic since 2010. In two years of observation samples from 27 measurement places were processed in the 105 years old spruce monoculture. The CO$_2$ flow was measured using a portable closed gazometric system LI 8100 (LI-COR Inc. USA). Before the measurements the humus horizons were separated from mineral horizons by inserting a sharp metal sheet. All the soil with roots, situated in the circle measurement camera over the metal sheet, was sampled and analyzed. Following soil parameters were measured: dry weight, C/N ratio, tota carbon (TC), total organic compounds (TOC), inorganic carbon (IC), pH H$_2$O and pH KCl. Concerning roots, following parameters were determined: dry weight of individual root categories (< 1 mm, 1–2 mm, 2–5 mm, > 5 mm), C/N ratio, ergosterol, ergosterol/B-sitosterol ratio, cycloartenol/ ergosterol ratio, cycloartenol/ B-sitosterol ratio.

On the basis of two years experiments, significant dependence of N content in fine roots and sitosterol content in the soil were significantly correlated with CO$_2$ flux from soil. It seems that sitosterol content in the soil interrelates someway with fine root and mycorrhiza quantity. Other studied parameters did not prove statistically significant correlation with values of soil respiration. It could be caused by small quantity of samples analyzed. Next replicates were obtained in last growing period of observation and results are in data processing stage. Nevertheless, the determination of the complicated interrelationships between CO$_2$ flux from soil and roots and rhizospheric and soil microflora will demand still more complex experiments and observation in future.

Using spatially disaggregated Yasso07 predictions to estimate Norwegian forest soil C change for the UNFCCC – exploring the sensitivity to fine root turnover

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Abstract

Norwegian forest soil C estimates for the UNFCCC rely on model predictions with input generated from the National Forest Inventory data (NFI). We show a methodology where the national C change estimate for the Forest remaining Forest category takes into account the observed variability in site productivity and climate. The decomposition model Yasso07 (Liski et al. 2005, Tuomi et al., 2009, 2011a, 2011b) is applied on a total of 11 200 individual NFI plots with time series of standing tree biomass back to 1990. We apply plot information on climate, stand age, site-index, biomass distributed to three dominant tree species and annual litter turnover rates. Litter from ground vegetation is estimated from models. In addition, based on NFI data, the input of litter from natural mortality and harvest activities is included. Estimates of soil C stock and soil C change are presented across site variables such as site index, tree species, stand age and climate. Estimated soil C stocks are compared to measured stocks for a subset of the plots (deWit and Kvindesland 1999). The sensitivity of the estimated C stock and C change on the chosen turnover rates is explored.

Model estimates of C stock and C change were highest for Norway spruce, on sites of high site-index and lowest for Birch ssp. / deciduous stands and sites of low site-index. Change estimates across stand age showed emissions for young stands – up to a stand age of ca. 25 years – followed by an increase in C accumulation stabilizing at stand age ca 35 years. Estimates of C stocks were generally low compared to measured C stock with the best agreement found in plots with cold and dry climate and well drained conditions. Increasing fine-root turnover by 100% for the three tree species and two ground vegetation layers showed an overall increase in C stock of ca. 30 %. Conclusions are that the methodology relies on a model application showing the expected dynamics due to site productivity and stand dynamics. The model does not reproduce measured C stock on poorly drained sites. Fine-root turnover is one among many parameters that need to be investigated in the future work with this method.

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Mineralomass and simulated yield by stump removal in root systems of *Pinus pinaster* in south-west France

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Abstract

The Landes forest, south-western France, produces 1/5 of french wood, but was hit by two major storms in 1999 and 2009 which halved the stocking in this forest. Wood industry absorbs already all the wood production, but fuelwood power plants have settled down in this area in recent years. Therefore there is an increased interest in yielding stumps and branches in this forest, and in other forested areas in the world. However, increasing biomass removal, and hence nutrients, has raised concerns about the sustainability of site fertility and forest productivity.

We estimated biomass stocks of below-ground biomass from a sample of 72 harvested trees. Additionally, fine roots were collected at the stand level. We measured the nutrient (N, P, K, Ca, Mg) contents of the different root compartments (stumps, coarse and thin roots). Different scenarios, including harvests of above and below-ground compartments were used to assess the corresponding biomass and nutrient exports. The quantification of the effect of different scenarios of stump harvest was achieved by 3D digitized data of root architecture of a sample of root systems in which virtual harvesting could be done.

This permitted to show that nutrient concentration only depends upon root diameter and not upon root type (e.g. sinker, taproot, shallow horizontal root). Nutrient contents exhibit small variation for cross sectional diameters larger than 1 cm, and increase dramatically for smaller roots. Nutrient losses were much higher in canopy harvest scenarios than in root harvest scenarios. This was mainly due to higher nutrient contents of needles whereas in roots, higher nutrients contents are only found in fine roots which were only marginally harvested by stump removal.

Stump and large root harvest, collecting roots only in the close vicinity of the stumps, could be sustainable, but not foliage harvest. However, stump harvest has other incidences on soil and ecosystem.

Carbon allocation in fine root and hyphal respiration using a ^{13}C pulse labelling approach

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Abstract

Studying carbon allocation in trees is a key to better understand the belowground carbon cycle and its response to climate change. Tracing ^{13}C in tree and soil compartments after pulse labelling is one of the most powerful tools to study the fate of carbon in forest ecosystems.

This study was conducted in Yamashiro experimental forest, Kyoto, Japan. Branch pulse labelling was done 7 times in 2011 using the same branch of *Quercus serrata* (H: 11.7 m, DBH: 33.7 cm) to see seasonal variations of carbon velocity. Whole crown labelling of *Quercus serrata* (H: 9 m, DBH: 13.7 cm) was done in 2012 to study carbon allocation and to especially focus on belowground carbon flux down to hyphal respiration. Pure $^{13}CO_2$ (99.9%) was injected to the labelling chamber which was set either to the branch or the crown. Then, after respectively one hour of branch labelling and 3.5 hour for crown labelling, the chamber was opened. Trunk respiration chambers, fine root chambers and hyphae chambers were set to the target tree to trace labelled carbon in the CO_2 efflux. 41 μm mesh was used to exclude ingrowth of roots into hyphae chambers.

The results show that the velocity of carbon through the tree varied seasonally, with higher velocity in summer than autumn, averaging 0.47 m h^{-1}. Half-lives of labelled carbon in autotrophic respiration were similar above and below ground during the growing season, but they were twice as long in the trunk relative to the roots in autumn.

From the whole crown labelling performed at the end of growing season, the $^{13}CO_2$ signal was observed 25 hours after labellling in the trunk chamber and almost simultaneously, 34–37.7 hours after labellling, in fine root and hyphal respiration. Half-lives of ^{13}C were longer in the trunk than belowground. Trunk respiration was still using labellled carbon during winter suggesting that winter trunk respiration is partly fuelled by carbon stored in the trunk at the end of the growing season.

Decomposition of *Ceratonia siliqua* litter in a Mediterranean ecosystem, Turkey

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Abstract

Litter is the main pathway for the return of organic matter and nutrients in terrestrial ecosystems. Decomposition of litter is the main source for the biological carbon turnover in the world. Litter decomposition is strongly influenced by climatic variables, litter quality and microbial activity.

This study was conducted to investigate the relationship between litter quality and decomposition rate of *Ceratonia siliqua*. Litters of this plant were analyzed for determining of total carbon, nitrogen, phosphorus, lignin and cellulose contents (%). The litter bag technique was used to determine its mass loss in the field for 9 months.

There was a significant difference in carbon, nitrogen and phosphorus contents of litter between the seasons (P≤ 0.05). Litter bag mass also showed a decrease. Decomposition rate of litter for 3, 6 and 9 months were 33.13, 35.24 and 41.42 % respectively.

Litter decomposition of *Ceratonia siliqua* did not significantly affect organic matter and nutrient turnover over 9 months.

Keywords: Decomposition, litter quality, *Ceratonia siliqua*, organic matter turnover

Validation of the Yasso07 soil carbon model for estimating dynamics of soil, litter and deadwood C stocks in Swiss forests

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Abstract

Parties of the United Nations Framework Convention on Climate Change have committed to submit annual national greenhouse gas inventories (GHGI) to the Climate Change secretariat. CO_2, one of the major greenhouse gases, is removed from the atmosphere and stored as C in living and dead biomass and in the soils of terrestrial ecosystems. Generally, forests are major C stores. Important drivers of C stock changes in soil, litter and deadwood on forest land are climate and C inputs from annually accumulating dead organic matter (DOM).

Switzerland, among other countries, applies Yasso07 (Y07), a model of C cycling in mineral soil, litter and deadwood, for estimating temporal dynamics of C stocks on forest land for its GHGI. Y07 was developed for general application with low parameter and input requirements. For estimating stocks of organic C in mineral soils, Y07 requires information on C inputs from DOM (foliage, fine and coarse roots, coarse standing and lying dead wood) and climate (temperature and precipitation). Decomposition of the different litter types is modeled based on their chemical composition, diameter of woody parts and climate.

To test the validity of the model in Swiss forests, we validated Y07 using empirical data from a long-term litter decomposition experiment and from the Swiss NFI. Y07 was run using three published parameter sets (Tuomi et al. 2009, 2011; Rantakari et al. 2012) to reproduce a) measured C mass loss in foliage and fine root litter at 5 sites over 5 years and b) changes of observed C stocks in deadwood from the Swiss NFI. The simulated C mass loss and change in deadwood C stock differed for the three Y07 parameter sets indicating their individual decomposition sensitivities to climate. Based on a RMSE analysis, the closest match between measured and simulated C mass loss in foliage and fine root litter was obtained with the parameter set from Rantakari et al. (2012). With this parameter set, Yasso07 also reproduced the change in the mean measured C stock from 708 NFI sites from 2005 (measured: 6.115 Mg C ha^{-1}; estimated: 6.235 Mg C ha^{-1}) to 2011 (4.854 Mg C ha^{-1}; 4.865 Mg C ha^{-1}).

We conclude that Y07 is a valid tool to accurately estimate temporal changes in soil, litter and deadwood C stocks in Swiss forests. For the Swiss GHG inventory, the application of Y07 implies improvements in transparency, consistency and comparability over previous inventories. We identified items for further improving the accuracy of Y07 for application in Swiss forests, including a) a better estimation of the ratios of the chemical C fractions of the litter and deadwood inputs and b) a finer separation of the size of the deadwood input.

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Simulating effects of whole tree harvest on humus carbon and nitrogen content in a Norwegian spruce stand

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Abstract

Norway is planning to increase the production of bioenergy by up to 14 TWh before 2020. A large proportion of this is expected to be based on feedstuff from forest resources, among others from a more complete use of the biomass harvested, by including residues like branches and tops which are not much used today. In order to estimate the effect of this increased removal of biomass on organic matter in forest soils, a modelling approach, using the COUP model, was chosen.

The model was parameterised using a whole tree thinning experiment in a spruce stand in South-Eastern Norway. Based on the parameterisation, two different harvest regimes were simulated: conventional harvest and whole tree harvest. In the model, conventional harvest was simulated by removing 80% of the stem and branches, but not removing any needles. Whole tree harvest was defined as the removal of 95% of the aboveground stem and branch biomass plus the removal of 47% of the needle biomass.

Predicted C and N content change in the soil humus pool after conventional harvest was in a similar range as simulated by thinning at a stand age of 33 years. After whole tree harvest, somewhat lower C and N contents in the humus pool were found. However, concentrations of C and N were still increasing in the first years after harvest rather than decreasing, mainly due to decomposition of roots. The simulations suggest that as long as only stems, tops and branches are removed from the forests, organic matter content in the soil will not decrease. Thus, the additional utilisation of tops and branches after harvest in order to increase available biomass for energy can be recommended as no significant negative effect on soil organic matter content was found.

Production and turnover of biomass and necromass of extramatrical mycelia of mycorrhizal fungi under elevated CO_2 and nitrogen fertilisation - the use of chemical markers and a modelling approach

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Abstract

Very little is known about the turnover of extramatrical mycelia of ectomycorrhizal fungi in forest soils. We used sand filled mycelial ingrowth bags harvested at various intervals and applied ergosterol as a proxy for living biomass and chitin as a proxy for total dry matter, living or dead. A simple modeling approach was used to estimate the daily biomass production and turnovers of biomass and necromass. We applied this technique in a Free-Air Carbon Enrichment (FACE) and N-fertilization experiment located in a *Pinus taeda* plantation. Preliminary results suggest a fast turnover of the biomass while the necromass was turned over more slowly.
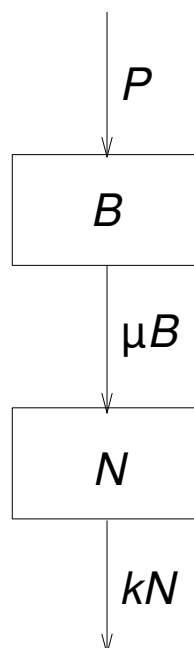
Figure 1. The model describing extramatrical mycelia production and turnover. *B* is live biomass, *N* is dead biomass (necromass), *P* is production rate of new biomass, μ is specific mortality of biomass, and *k* is specific decay rate of necromass.

Cold ecosystems in a warmer world: tracing radiocarbon in plant and soils of high altitudes at different soil temperatures

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Abstract

Treelines are ecotones characterised by a sharp shift in vegetation form, from closed canopy forest to treeless vegetation. The mechanisms responsible for such an abrupt transition in growth form are not well understood to date. The fact that treelines have frequently been associated to mean temperatures of about 6°C during the growing season suggests low temperature to be the principal factor preventing trees from growing at higher elevations. However, it remains unclear whether air or soil temperature limits plant growth, and whether belowground C allocation and plant growth respond similarly to temperature changes. The aim of our study was to test whether, and how, soil temperature affects net plant carbon assimilation and allocation under treeline conditions, with air temperature remaining unchanged. In order to test this, we established a soil temperature manipulation experiment in the Swiss Alps, at 2280 m a.s.l, with each a naturally occurring tree (*Pinus mugo*) and a forb species (*Leucanthemopsis alpina*). The soil temperature treatment included ambient soil temperatures (control), warming by 6°C, and cooling by 6°C (average across top 10cm of soil), from the end of June to mid-August 2012. Plants were pulse-labelled with $^{14}CO_2$ under the respective temperature conditions and ^{14}C was quantified in plant tissue, soil microbial biomass, soil organic matter, dissolved organic carbon, and soil respiration.

Plants grown in cooled soil had a lower root biomass compared to plants grown in warmed and ambient temperature soil. The allocation of ^{14}C labelled assimilates correlated positively with soil temperature, both in below- and aboveground plant parts. Total soil respiration increased exponentially with soil temperature, while ^{14}C in soil respiration supported the existence of a temperature threshold for carbon metabolization below ground. In fact, while the amount of soil-respired $^{14}CO_2$ did not differ between warmed and control treatments, much less $^{14}CO_2$ was respired in the cooled treatment (-84% for *P. mugo* and -26% for *L. alpina*, respectively; changes relative to the ambient treatment). A similar pattern was observed for ^{14}C in microbial biomass, probably reflecting suppressed rhizodeposition at lower temperatures. These findings suggest that soil respiration responds continuously to temperature changes, while rhizodeposition of recently-fixed assimilates shows a threshold-driven response.

Fine root production in mature white poplar grown in periodically flooded and unflooded riparian forests in Poland

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Abstract

Natural habitats of white poplar (*Populus alba* L.) are flood-dependent forests, however this species is cultivated often in variable environments, such as fields, forest edges, grassland and urban habitats. We examined fine root production in root systems of mature white poplars grown in three forests situated on the right bank floodplain of the Vistula River: 1) Ostrów Panieński Nature Reserve, 2) Kępa Ostromecka Nature Reserve 3) Ostrów Panieński – poplar monoculture. The sites 1 and 2 represent natural forests protected because of the rare riparian forest associations (*Ficario-Ulmetum minoris* and *Salici-Populetum*) with old poplar trees (70–100 and 150–200-year-old, respectively). The site 3 is a monoculture of white poplars about 50–60-year-old. Soils of the forest sites had similar pH (7.22, 7.35, 7.41, respectively) and similar salinity. Concentrations of available mineral nutrients did not differ significantly between the study sites, except concentrations of P and Ca, which were the highest in the site 2. The sites 2 and 3 are characterized by cycling flooding, and the site 1 remains unflooded since a dam on the Vistula River was built in 1970. Fine roots (<1, 1–2 and 2–3 mm in diameter) were sampled by soil coring in three soil levels (1–10, 11–20, 21–20 cm) under white poplar canopies. Morphological features of the tree fine roots, such as root length, volume, and root tip number were determined using an image analysis system, and the root biomass was weighed. The results indicated that fine root biomass and morphological characters were significantly higher in the sites 2 and 3, flooded every spring and middle summer, than in the unflooded site 1. Most fine roots of white poplar (63-70%) were concentrated in the upper 10 cm of the soil profile in the all study sites. The number of fine roots in this soil level ranged from 472 (per 200 cm^{-3}) in the unflooded site 1 to 1280 in the in periodically flooded poplar monoculture. The forest sites differed in vertical distribution pattern of poplar fine roots. At the sites 1 and 3 the fine root abundance decreased with the soil depth, however in the nature reserve Kępa Ostromecka (site 2) similar abundance of fine roots in the soil levels 11–20 cm and 21–30 cm was found. The data suggest a favorable effect of periodic flooding on fine root production in white poplar root systems; however the tree age and competition of other tree species could also play a role in fine root proliferation.

Tree species diversity interacts with elevated CO_2 to induce a greater root system response

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Abstract

As a consequence of land use change and the burning of fossil fuels, atmospheric concentrations of CO_2 are increasing and altering the dynamics of the carbon cycle in forest ecosystems. In a number of studies using single tree species, fine root biomass has been shown to be strongly increased by elevated CO_2. However, natural forests are often intimate mixtures of a number of co-occurring species. To investigate the interaction between tree mixture and elevated CO_2, *Alnus glutinosa*, *Betula pendula* and *Fagus sylvatica* were planted in areas of single species and a three species polyculturein a free-air CO_2 enrichment study (BangorFACE). The trees were exposed to ambient or elevated CO_2 (580 µmol mol^{-1}) for four years. Fine and coarse root biomass, together with fine root turnover and fine root morphological characteristics were measured. Fine root biomass, and morphology responded differentially to elevated CO_2 at different soil depths in the three species when grown in monocultures. In polyculture, a greater response to elevated CO_2 was observed in coarse roots to a depth of 20 cm, and fine root area index to a depth of 30 cm. Total fine root biomass was positively affected by elevated CO_2 at the end of the experiment, but not by species diversity. Our data suggest that existing biogeochemical cycling models parameterised with data from species grown in monoculture may be underestimating the belowground response to global change.

Nine years of irrigation cause vegetation and fine root shifts in a water-limited pine forest

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Abstract

Scots pines (*Pinus sylvestris L.*) in the inner-Alpine dry valleys of Switzerland suffer from increased mortality during the past decades. Reasons are longer and more frequent dry periods. Meanwhile, a proceeding replacement of the Scots pines by pubescent oaks (*Quercus pubescens* Willd.) has been observed. In 2003 an irrigation experiment was installed to track the changes by reducing the drought pressure on the natural pine forest. After nine years of irrigation we observed major adaptations of the vegetation and shifts in the Scots pine fine root abundance and structure. Irrigation permitted new plant species to assemble and promoted canopy closure with a subsequent loss of herb and moss coverage. Fine root dry weight increased under irrigation and the fine roots had a tendency to elongate. Fine root morphology (specific root length SRL, root tissue density RTD) of the two dominant tree species reacted contrariwise to irrigation with the fine roots of Scots pine having increased SRL but decreased RTD, and with the fine root of pubescent oak reacting contrary. Structural composition of fine roots remained unaffected by irrigation expressing preserved proportions of cellulose, lignin and phenolic substances. A shift to a more negative δ^{13}C signal in the irrigated fine root C indicates an increased photosynthetic activity of the pine trees. Using radiocarbon (^{14}C) measurement a reduced mean age of the fine roots in the irrigated plots has been determined. Reasons for this are either an increase of newly produced fine roots, as the increase in fine root biomass verifies, or a reduced life span which corresponds to an enhanced turnover rate. Overall the responses belowground to irrigation are less conspicuous than the more rapid adaptations aboveground. Lagged and conservative adaptations of tree roots with decadal lifespan are challenging to detect hence demanding for long-term surveys. Investigations concerning fine root turnover rate and degradation processes under a changing climate are crucial for an entire understanding of the C cycling.

Detection frequency can vary with orientation of roots in *Pinus thunbergii* forests using ground penetrating radar

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Abstract

Ground penetrating radar (GPR) can detect tree roots under specific conditions (Guo et al. 2013) but detection frequency is affected by several factors such as water contents of roots and soils, root diameter and root positions (Hirano et al. 2009). In coastal *Pinus thunbergii* forests, GPR detection frequency was 54% for the number of roots larger than 1.0 cm in diameter (Hirano et al. 2012). One of the limiting factors we have not considered is root orientation with which the horizontal angles of the roots crossed at a scanning line (Butnor et al. 2001). Under experimental sand conditions, the clear hyperbolas reflecting roots were observed when the radar was crossed at a 90° angle, whereas it was difficult to identify the trace of hyperbola when the angles were less than 45° and larger than 135° (Tanikawa et al. submitted under review). Here, we measured the horizontal angle of the roots crossed at the scanning line in *Pinus thunbergii* forests and calculated the angle distribution of the number of roots.

Two different stands of *Pinus thunbergii* grown in sandy soils in coastal forests were selected and three plots with three 4-m parallel transects were set in each site. Radar profiles in each transect were scanned using 1.5 GHz GPR. After scanning, each transect was progressively excavated down to 30 cm depth to evaluate vertical distribution, diameter and horizontal angle of roots.

We measured angles of 143 and 169 roots larger than 1.0 cm in diameter in each stand. The frequency of roots that have angle ranging from 45° to 135° was 62% and 50% in each stand, which is in a similar range to the radar detection frequency such as 54%. These results suggest that the roots that have an angle of 45° – 135° can be detected as hyperbolas in the radar profiles. Therefore, grid transects instead of parallel transects would be needed to detect the whole roots using GPR in the forest field.

Keywords: coarse roots, detection frequency, *Pinus thunbergii*, root diameter, root orientation

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Carbon, nitrogen, phosphorus and sulphur concentrations in relation to soil type under different land use

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Abstract

Carbon (C), nitrogen (N), phosphorous (P), and sulfur (S) are key elements of all biogeochemical processes. Studies of interactions among these elements provide valuable information for understanding functions of ecosystem and effects of anthropogenic influences on soil productivity. This study aims to compare total C, N, P, and S concentrations in adjacent cultivated and natural grassland soils under different site conditions in central part of Bosnia and Herzegovina. Observed soil layers were 0–10 and 10–30 cm deep. Carbon and N concentrations were analyzed by using element analyzer, and HNO_3 pressure digested P and S concentrations were analyzed by ICP technology. Significantly ($p < 0.05$) lower mean concentrations of C, N and S were detected at all three investigated sites in cultivated soils in relation to uncultivated grassland soil. Substantially higher concentrations of P were detected in cultivated soil in relation to adjacent uncultivated soils.

Keywords: carbon, nitrogen, phosphorous, and sulfur concentrations, ecosystem functioning

Bryophytes regulate carbon and nitrogen cycling in Boreal forest

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Abstract

Bryophytes are often found in abundance in the understorey of Boreal forests. Because they have low productivity and limited capacity to acquire nutrients from soil organic matter, it is frequently assumed that they contribute little to biogeochemical cycling in forests. Close observation of the moss layer, however, often reveals that they interact with ectomycorrhizal mycelia, which is concentrated at the interface between new growth of green moss tissue, and the brown senescing tissue situated above the fermentation horizon. Moreover, the thickness of many bryophyte layers in Boreal forest also means there is potential to influence abiotic variables that are known to be important regulators of biogeochemical cycles. Here we test the hypotheses that the moss layer affects soil CO_2 efflux by influencing a) soil moisture and temperature, and b) the activity of extraradical ectomycorrhizal mycelium.

We established plots in Culbin forest National Nature Reserve in Morayshire, Scotland, in which the surface layer of mosses was either removed, or removed and re-laid (controls). We subsequently measured soil CO_2 efflux *in situ* using a LICOR 8100 and soil moisture and temperature at various intervals from June 2011 to October 2012. A separate microcosm experiment was established to test how ectomycorrhizal mycelium interacts with both moss and Scots pine needle litter to affect reciprocal transfer of ^{13}C from host plant and ^{15}N acquisition from the litter.

On average, 1.4 times more CO_2 was released from soil surface in the presence of moss compared to when moss was absent. Soil moisture and mean soil temperature did not change in response to moss removal, but where moss was absent, the soil temperature tended to be colder at night and warmer during the day. At the time at which soil CO_2 efflux was measured (approx midday), there was no difference in the relationship between this flux and temperature between moss removal and control plots. However, analysis of temperatures taken earlier in the day (1 am) showed that temperature differences between treated plots did explain some of the variation in soil CO_2 efflux. The microcosm experiment showed that Scots pine needle litter was poorly colonised by the ectomycorrhizal fungus *Paxillus involutus* mycelium compared to moss litter. Significantly more ^{15}N was acquired from the moss litter than the pine needles, and this resulted in more recently assimilated ^{13}C being allocated to the moss litter.

Our results show that mosses have crucial roles in regulating carbon and nitrogen cycles in Boreal forests, despite their limited capacity to acquire mineral nutrients and carbon directly. The ability of ectomycorrhizal fungi to colonise moss tissue is likely to be a key factor that influences carbon and nitrogen fluxes, but the effects of moss in buffering soil temperature fluctuations, with subsequent impacts on microbial activity, is also crucial.

Modelling carbon stock changes in Icelandic soils, a climate change perspective

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Abstract

Introduction
The subarctic region has been considered an area of high impact under future climate change scenarios. We investigated the climatic effect on the change in potential forest distribution, structure and carbon stock in Iceland from 1900 to 2100 by applying climatic time series to the dynamic vegetation model LPJ-GUESS.

Methods
For the historical period we utilized a combination of gridded climatic datasets to create a time series for monthly means of temperature, precipitation and radiation. These datasets where provided by the Icelandic Metrological office (IMO) and the Climatic research unit at East Anglia (CRU). For the future climate we added data from three different general circulation models (GCM´s) where each model had three different representative concentration pathways (RCP). In order to compensate for topographical differences within modeled grid cells we divide each grid cell into elevation zones with 50 meters vertical interval. Each elevation zone is modeled explicitly with downscaled temperature values adjusted for the elevation. This gave us the opportunity to observe different ecosystems with in each grid cell and how they developed over time both horizontally and vertically. The model was then forced with the climate data to produce results for each climate change scenario.
The model we used includes the features of the LPJ-GUESS model with an added module where nitrogen is modeled explicitly. The addition of the nitrogen cycle allowed us to examine the nitrogen availability in soils and its effects on vegetation growth and carbon stock changes.

Results
Our results show a gradual increase in soil carbon under most climate change scenarios in Iceland. One GCM shows a slight reduction under two scenarios. Most important changes are in higher elevation with the vertical climb of the forest limit and, therefore, an increase in vegetated land area, up to 20 thousand square kilometers at the end of the scenario. Our results show large uncertainties in the future effects of climate change on vegetation dynamics and soil carbon stocks. Including nitrogen limitation on vegetation growth plays a great role when estimating future soil stocks with dynamic vegetation models. Effects of nitrogen deposition and CO_2 fertilization are small compared to the effects of nitrogen limitation on the total results.

Changes in ectomycorrhizal community composition, root tip abundance, mycelial production and N-uptake as influenced by nitrogen deposition

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Abstract

Nitrogen (N) availability is known to influence ectomycorrhizal fungal components such as fungal community composition, biomass of root tips and production of mycelia. Here we integrate results obtained from a stand-scale N-deposition gradient (forest edge at Thyregod) and a N-fertilization experiment (the Klosterhede NITREX plot). We also present ongoing research at two new N-deposition gradients at forest edges in Klosterhede and Sdr. Omme. We concurrently measured the abundance of ectomycorrhizal root tips, production of external mycelia and explored the changes in the ectomycorrhizal community composition. At Thyregod we also traced the fate of ^{15}N-labeled nitrate, ammonium and glutamic acid into soil, roots and mycorrhizas after 24h incubation. At Thyregod, ectomycorrhizal root tip abundance and mycelial production decreased 5 and 10-fold, respectively, with increasing N deposition. Also, the ectomycorrhizal fungal community changed and the species richness decreased. The changes were correlated with the measured indices of N status, especially N deposition and N leaching. In contrast, the only measurable mycorrhizal parameter that changed with N-addition at the NITREX site in Klosterhede was a decrease in species richness while production of mycelia and dominant mycorrhizal fungi remained unchanged. In Thyregod, we showed that roots and fungi preferred ammonium over glutamic acid over nitrate. Currently, we are setting up mycelial production measurements at the two new N-deposition gradients in Klosterhede and Sdr. Omme as well as analyzing the changes in overall fungal community structure (both ectomycorrhizal and saprotrophic fungi) along the gradient in Klosterhede.

Key-words: ectomycorrhiza, external mycelial production, community composition, nitrogen deposition, forest edges, NITREX, *Picea abies*

Modeling of calcium dynamics in soil organic layers

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Abstract

Calcium is a major nutrient regulating metabolism in a plant and its bioavailable form can be found in the soil cation exchange complex and soil waters.

Here we present a model of soil calcium dynamics developed on the base of the model of soil organic matter dynamics ROMUL. ROMUL describes the mineralization and humification of the fractions of fresh litter which is further transformed into complex of partially humified substance and then to stable humus depending on temperature, soil moisture, pH and chemical composition of the fraction (nitrogen, lignin and ash contents). We assume that calcium dynamics follow the same dynamics as soil organic matter in the ROMUL model, but differ in coefficients' values. The difference can be expressed as amendments/multipliers to the ROMUL coefficients which we can evaluate using experimental data obtained from sites which can be considered as being in steady state. The model describes calcium flows between pools of soil organic matter – amounts of pools of plant nutrition, leaching, synthesis of secondary minerals. We used experimental data for calibration of the model from spruce forest in Rila Mountain (Bulgaria) assuming that it is in steady state. Such model structure allows analyzing the response of forest soil to strong external impacts like forest clear cuttings.

We developed a corresponding scenario based on existing experimental data and simulated the soil dynamics and changed organic matter flow in the forest ecosystem after clear-cut. Organic matter and calcium are accumulated in forest floor short time after clear-cut due to increased root litter and cutting residues. Then total organic matter amount as well as nutritive elements are decreasing and could be recovered only after formation of forest floor depending on forest type. The highly increased pool of exchangeable calcium follows different ways of dynamic in dependence on water regime: for leaching, for bonding exchangeable Ca in soil cation exchange complex, for secondary minerals of calcium as a pool of calcium oxalates. After extreme impacts the Ca pools in forest floor and the exchangeable Ca are increased in comparison with steady state where these pools are decreasing. Exchangeable Ca is increasing more slowly. Calcium is significantly accumulated in stable humus forms after cutting. We assumed that Ca leaching also is increased after cutting.

The response of calcium pools in forest soil after catastrophic external impacts (clear cutting as an example) shows strong relation to development of vegetation. Forest ecosystems in a whole can reduce the negative effects of this influence by leaching of excessive calcium but too much depletion can lead to its deficiency for further forest growth.

Standing stock and production of fine roots – a comparative study in young beech and spruce stands

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Abstract

The study was focused on two young forest stands, an evergreen (Norway spruce) and a deciduous (European beech) stand, both approximately 15 years of age. The site is characterized by optimum ecological conditions for beech, but is at the southern boundary of natural distribution of spruce in Slovakia. Fine root standing stock (soil cores) and production (in-growth bags) were followed during 2009–2012. To estimate fine root production, two sets of in-growth bags retained in soil for one year or two years were implemented. Beech produced large biomass inside the bags during the first year, followed by smaller production in the second year. Spruce, on the other hand, occupied the new space inside the bags more intensively during the second year. We combined the data from one-year- and two-year-old in-growth bags to estimate mean fine root production for both species. Results on fine root standing stock and production were analyzed in terms of meteorological conditions, namely monthly precipitation and temperatures.

Fine root biomass at the soil depth 0–50 cm oscillated between 6.08 and 7.42 t ha^{-1} in beech and from 5.10 to 6.49 t ha^{-1} in spruce. Annual fine root production (soil depth 0–30 cm) was between 1.11 – 1.63 and 0.95 and 1.54 t ha^{-1} in beech and spruce, respectively. We found out that fine root standing stock (measured in spring) was very closely related to the meteorological conditions of the previous year. Fine root production, however, was strongly influenced by meteorological situation in the current year. For instance, in 2010 (excessive precipitation in the entire growing season) production of fine roots in both stands prevailed to fine root mortality. On the other hand, in 2011 (lack of precipitation especially in April and May) mortality of fine roots was larger than their production. We conclude that although standing stock of assimilatory organs was much larger in spruce (ca. 20 t ha^{-1}) than in beech stand (ca. 5 t ha^{-1}), standing biomass and necromass of fine roots did not differ significantly between the forest types. Similarly, while the turnover of assimilatory organs was circa four times faster in beech than spruce, turnover of fine roots was conformable. Moreover, high quantity of fine root biomass indicated that the stands might represent growth stage (shortly after canopy closure) nearing maximum allocation of carbon into fine roots. The expanding nature of these stands is reflected by the low turnover of fine roots (0.25 and 0.24 per year in beech and spruce, respectively).

Keywords: *Fagus sylvatica, Picea abies,* fine root biomass and necromass, inter-annual fluctuation, metrological conditions

Influence of dominant tree species on spatial distribution of soil properties in boreal forest

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Abstract

The aim of the research was to assess spatial distribution of parameters of soil fertility in boreal forests. It is known that the biodiversity and productivity of ecosystems depend on availability of resources that are needed for living organisms for normal development and functioning. Forest ecosystem provides most of the needed resources (nutrient elements, water etc.) but quite often their forms are not available for biota. For a better understanding of ecosystems' current condition and functioning it is important to know as background characteristics (to assess potential opportunity to use resources) as directly available resources. But usually available resources are not distributed homogeneously across ecosystems. A main reason for heterogeneity of forest ecosystems is heterogeneity of soil properties that is mostly defined by the properties of dominant plant species, landscape position and anthropogenic activity.

We studied soil parameters in three types of forests: 170-year-old pine, 70-year-old pine and 25-year-old birch forest. In the 70-year-old forest 2 sample plots that differed in forest management (30% thinning and without thinning) were chosen. All sample plots are located on the same soil type and under the same climate conditions which gives us the opportunity to compare the heterogeneity of these plots. To estimate the influence of dominant species on soil properties, samples were collected from 3 compartments: near the trunk, at middle crown projection and from forest gaps. For assessing the impact of belowground vegetation, we studied the plant and root biomass, available forms of nutrient elements (Ca, Mg, K, Na, AL, Fe, Mn, Zn, Ni, Cu, P, S), parameters of soil acidity (pH, exchangeable and hydrolytic acidity), C and N content.

We hypothesized that:
1. Dominant tree species and aboveground vegetation is one of the main factors that define spatial distribution of nutritional resources in soil.
2. The influence of dominant species on soil fertility depends on the type of forest, its mosaic structure, and successional stage.

Keywords: soil heterogeneity, soil fertility, boreal forest, nutrient elements

Does the increased air humidity affect soil respiration and carbon stocks?

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Abstract

Climate manipulation experiments at ecosystem-scale enable us to simulate, investigate and predict changes in carbon balance of forest ecosystems. Considering the predicted increase in air humidity and precipitation for northern latitudes, this work aimed at investigating the effect of increased air humidity on soil respiration, distribution of soil organic matter (SOM) among pools having different turnover times, and microbial, fine root and rhizome biomass. The study was carried out in silver birch (*Betula pendula* Roth.) and hybrid aspen (*Populus tremula* L. x *P. tremuloides* Michx.) stands in a Free Air Humidity Manipulation (FAHM) experimental facility containing three humidified (H; on average 7% above current ambient levels since 2008) and three control (C) plots. Soil respiration rates were measured monthly during the growing season using a closed dynamic chamber method. Density fractionation was adopted to separate SOM into two light fractions (free and aggregate-occluded particulate organic matter, fPOM and oPOM respectively), and one heavy fraction (mineral-associated organic matter, MOM). The fine root and rhizome biomass and microbial data are presented for silver birch stands only.

In 2011, after 4 growing seasons of humidity manipulation soil organic carbon contents were significantly higher in C plots than H plot (13.5 and 12.5 g C kg^{-1}, respectively), while soil respiration tended to be higher in the latter. Microbial biomass and basal respiration were 13 and 14% higher in H plots than in the C plots, respectively. Twice more fine roots of trees were estimated in H plots, while the total fine root and rhizome biomass (tree + understory) was similar in C and H plots. Fine root turnover was higher for both silver birch and understory roots in H plots. Labile SOM light fractions (fPOM and oPOM) were significantly smaller in H plots with respect to C plots (silver birch and hybrid aspen stands together), whereas no differences were observed in the contents of the more stable MOM. These results strongly suggest that, apart from the predicted increase in temperature and atmospheric carbon and nitrogen concentrations, an increase in free air humidity as a result of climate change may significantly influence the complex belowground carbon cycling by affecting biomass production, soil respiration and organic matter turnover.

The impact of afforestation on soil carbon dynamics in peaty mineral soils

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Abstract

Plantation forests occupy >10% of the Irish landscape and are a significant sink for carbon. While considerable progress has been made over the last decade in our understanding of carbon cycling in Irish forests, research has not addressed soil carbon stocks and fluxes in peaty mineral soils. While carbon stock changes in peat soils are assessed using emission factors and mineral soils using carbon stock changes it is unclear which method should be applied to peaty mineral soils. This project will be carried out on a chronosequence of Sitka spruce forests on peaty mineral soils with the following objectives.

1. To measure soil respiration at all sites and partition it into its autotrophic and heterotrophic components.
2. To measure soil carbon stocks at all sites and to assess the feasibility of detecting soil carbon stock changes using soil survey techniques
3. To measure root biomass and determine fine root turnover.

Soil respiration will be measured using a portable soil respiration chamber and will be partitioned between autotrophic and heterotrophic respiration using root exclusion collars. Fine root biomass will be determined using sequential coring and litterfall will be measured using litter collectors. Annual and seasonal budgets for autotrophic and heterotrophic soil respiration will be determined using statistical modelling. Soil carbon stocks will be estimated at each site using intensive sampling and age related changes in soil carbon stocks investigated.

Higher soil temperature and nutrient availability increase fine root turnover and litter production of Norway spruce

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Abstract

Climate change increases mean annual temperature and moisture especially in northern regions (ICPP 2007) which enhances mineralization and biological activity in the soil. This will affect fine roots and mycorrhiza, which are responsible for a substantial flux of carbon into the boreal forest soil (Helmisaari et al. 2002; Godbold et al. 2006). Yet, the contribution of belowground litter production to the carbon flux into the soil is largely unknown, especially in a changing environment.

Long-term manipulation experiments can provide data for detecting the possible changes in carbon allocation between the different tree compartments, and finding out if their turnover rate has changed. The aim of this study was to determine the carbon flux into the soil via belowground (fine roots) and aboveground (foliage) litter production after long-term soil warming (14–16 yrs, +5 C° higher temperature during growing seasons) and/or nutrient manipulation (22–24 yrs). Soil warming (W) was conducted with heating cables and as all plots were irrigated (I), the optimal nutrient solution (F) was provided with irrigation water. The annual fine root litter production (roots < 1 mm in diameter) was calculated by dividing the fine root biomass (Leppälammi-Kujansuu et al. 2013) by median fine root longevity, which was estimated by using a parametric regression model with Weibull error distribution. The aboveground litterfall was determined as a mean foliage litterfall, collected with litter traps for three years. The below- and aboveground litter production and their ratios in different treatments were compared and the total carbon flux was calculated.

Fine root survivorship differed significantly between the treatments (WFI, FI, WI and I). The shortest median longevity was in warming treatments (48 and 58 weeks in WFI and WI, respectively), especially in the mineral soil. In the fertilization treatment (FI) the median longevity was 1.5 years and in the reference treatment (I) nearly two years. As also the fine root biomass was high in the warmed and fertilized treatments, the annual fine root litter production, and thus the belowground carbon flux into the soil, was higher in all treatments compared to the I (Fig. 1). Only fertlization increased the aboveground litterfall. The total annual carbon flux into the soil was 1.8-3.0 times higher in the fertilization and/or warming treatments than in the I. We conclude that higher soil temperature and increased nutrient availability enhance the fine root turnover significantly which leads to substantial increases in the annual belowground litterfall production compared to the aboveground.
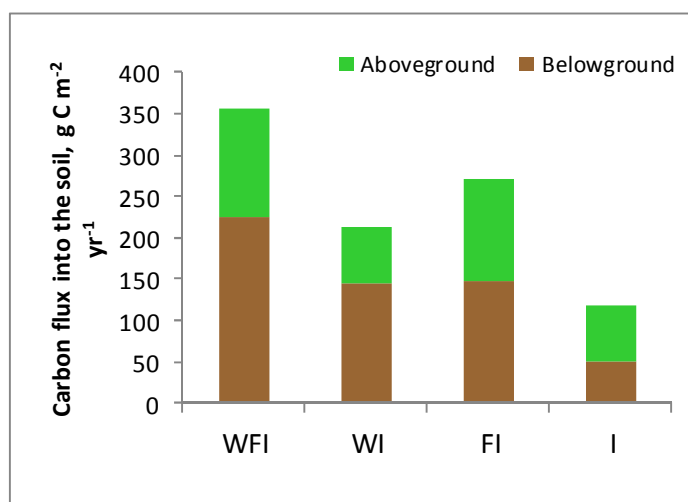
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Efficacy of fine roots increases with soil organic carbon and nitrogen stocks: example from pedunculate oak chronosequence

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Abstract

It is well known that trees growing on sites with poorer nutrient availability allocate greater share of carbon into roots at the expense of aboveground biomass growth. Consequently, a ratio of aboveground net primary productivity (ANPP) and fine root biomass ($FRB_{dry\ weight}$) could be used as a proxy for fine root efficacy (FRE) in production of aboveground biomass. In our work we tested the hypotheses that FRE depends on soil organic carbon (SOC) and total nitrogen (TN) stocks.

A chronosequence experiment was set up in April 2010, consisting of eight stands aged from 5 to 168 years with pedunculate oak (*Quercus robur* L.) as a dominant tree species. In 32 plots (four per stand), on approximately 640 trees in total, we have installed dendrometer bands for assessing ANPP. Litterfall was also periodically collected. At the beginning of 2012 we took totally 128 soil cores (4 per plot) down to 40 cm depth in the mineral layer. Each soil core was divided into four subsamples according to predetermined depths (5, 10, 20 and 40 cm). Bulk density, corrected for compactation, was determined for each subsample. Roots were extracted from soil samples and washed. Fine roots (d<2mm) were separated, dried at 105 °C and weighed. Soil type is stagnic luvisol with insignificant amount inorganic carbon in the top 40 cm. Hence, samples were analyzed for total C and N content with elemental analyser and SOC and TN stocks were calculated for each soil core.

ANPP ranged from 3.4 to 8.8 t C ha^{-1} yr^{-1} (excluding 5 yrs. old stand). $FRB_{d.w.}$ stocks ranged from 2.7 to 13.9 t ha^{-1}, with highest values observed in two youngest stands. SOC and TN stocks ranged from 55.9 to 122.4 t C ha^{-1} and 3.9 to 13.7 t N ha^{-1}, respectively, with CN ratio ranging from 8.8 to 16.4. $FRB_{d.w.}$ stock correlated negatively with both SOC ($R^2_{adj.}=0.39$) and TN ($R^2_{adj.}=0.44$), while FRE correlated positively with SOC ($R^2_{adj.}=0.31$) and TN ($R^2_{adj.}=0.43$). In addition, FRE correlated negatively with ln(CN), but the correlation was weaker ($R^2_{adj.}=0.25$). Further research is needed in assessing the role SOC, TN and CN ratio on fine root turnover rates and mycorrhiza.

Contribution of newly grown extramatrical ectomycorrhizal mycelium and fine roots to soil respiration in a young Norway spruce stand

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Abstract

Despite of the large contribution of extramatrical ectomycorrhizal mycelium (ECM) to annual belowground biomass formation, its role for soil respiration is a matter of debate. Here, we studied the contribution of newly grown ECM and fine roots of Norway spruce to soil respiration over two growing seasons in three different substrates.

Ingrowth mesh bags of 16 cm diameter and 12 cm height were placed in the upper soil and left for 12 to 16 months in 2010 and 2011. The 2 mm mesh size allowed the ingrowth of ECM and roots whereas a 45 µm mesh size allowed only the ingrowth of ECM. The mesh bags were filled with either EA horizon soil, pure quartz sand (QS) or crushed granite (CG, only 2011), each with 5 replicates. Five controls without any ingrowth were established for each substrate by solid tubes (2010) and by 1 µm mesh bags (2011). Emissions of CO_2 from the mesh bags and controls were measured biweekly by the closed chamber method with CO_2 determination by IRGA. ECM biomass was calculated as difference between fungal biomass (PLFA 18:2ω6,9) in mesh bags and controls. The contribution of roots + ECM and ECM to soil respiration was calculated as differences between emissions from mesh bags and controls.

Emissions of CO_2 were highest from QS mesh bags, reaching up to 120 mg C $m^{-2} h^{-1}$ in late summer of both years. Mean CO_2-fluxes from EA and CG mesh bags were lower than in QS.
The contribution of ECM to soil respiration was largest in QS, reaching cumulatively 1120 and 2175 kg C ha^{-1} during the 6 months growing season in 2010 and 2011, respectively. Cumulative CO_2 emissions from ECM in EA mesh bags were 450 in 2010 and 268 kg C ha^{-1} in 2011. From CG mesh bags, ECM derived CO_2 emissions were 874 kg C ha^{-1} in 2011.
The CO_2 emissions from 2 mm mesh bags, representing fine roots + ECM, were almost similar to those of the 45 µm mesh bags, suggesting a rather low effect of fine roots.

Biomass of ECM differed according to substrates, years and within replicates. However, correlations between ECM biomass in 45 µm mesh bags and their cumulative CO_2 emissions were not observed. On the contrary, such correlation was significant in 2 mm mesh bags of all substrates in 2011.

Our results suggest a larger contribution of newly grown ECM to soil respiration than of newly grown fine roots.

Organic carbon turnover along litter decomposition in black locust and poplar coppices, Germany

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Abstract

Litter quality plays an important role in organic matter decomposition and carbon sequestration. This study investigates OC turnover along litter decomposition at hybrid poplar (*Max 1*) and black locust (*Robinia pseudoacacia L.*) stands, Germany. To evaluate changes occurring during decomposition, litter bags experiment was established in November 2011. Litter bags were sampled every two months starting from Mar till Sep 2012, and analysed for changes in dry litter mass, C and N concentration. Solid-state ^{13}C CP-MAS NMR spectroscopy was used to assess the chemical structure of litter, and the chemical changes during decomposition. Populus and black locust litter differed in chemical composition and showed different patterns in litter decomposition at the beginning of experiment. Populus litter had higher contents of O-Alkyl-C and Aryl-C, while black locust litter had higher contents of Alkyl-C, Methoxyl-C and Phenol-C. In both black locust and populus, litter decomposition was associated with a decrease in O-Alkyl concentration and O-Alkyl-C/Methoxyl-C ratio; and a concomitant increase of Alkyl-C, Aryl-C; Methoxyl-C concentrations; index of decomposition (Alkyl/O-Alkyl ratio), hydrophobisity index ((Aryl+Phenol+Alkyl)/(Carboxyl+O-Alkyl)), and ratio of aromatic compounds to O-Alkyl C. Although concentration of fast decomposable O-Alkyl compounds was initially higher in populus than in black locust (61% and 54%, respectively), black locust had faster decomposition at the beginning of experiment (Nov-Mar), which could have related to the higher nitrogen content and lower C:N ratio compared to populus (18 and 45, respectively). After Mar, with a decrease in C:N ratio to 20, decomposition of populus litter increased. Despite initial differences in litter composition, after 9 month of experiment both litter had comparable concentrations for the most of C functional groups, with exception of Phenol-C, which was higher in black locust.

Effects of root- and hyphal-derived C on enzyme activity and nitrogen cycling under elevated CO_2

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Abstract

The stimulatory effect of elevated atmospheric CO_2 under global climate change on forest productivity has been predicted to decrease over time as pools of available N in soil become depleted, but empirical support for such progressive N limitation has been lacking. Increased N acquisition from soil depleted in inorganic nitrogen requires stimulation of the microbial processing of organic N, possibly through increasing C supply to soil by plant roots or mycorrhizal hyphae. Increases in (mycorr)rhizosphere C fluxes could stimulate microbes to produce extra-cellular enzymes that release N from SOM, feeding back from soil microsites to ecosystem-scale processes.

We investigated the influence of root exudation and hyphal turnover on soil enzyme activity and nitrogen mineralisation at the Duke Forest FACE site, USA, where loblolly pine (*Pinus taeda* L.) stands have been exposed to elevated CO_2 for 14 years and N fertilization for five years. Enzyme activities at three soil microsites (rhizosphere, hyphosphere, and bulk soil) were explored by the collection of intact soils from root box windows as well as by the adhering soil method. We measured soil C dynamics by a modification of the ^{13}C natural abundance technique. Study objectives were to analyze the influence (i) of atmospheric CO_2 on extra-cellular enzyme activities and (ii) of root- or hyphal-derived C on the activities of enzymes involved in N cycling and gross N transformations at soil microsites. Elevated atmospheric CO_2 significantly increased the activity of β-1-4-*N*-acetylglucosaminidase (NAG) in the rhizosphere by almost 2.5 times (39 to 95 nmol h^{-1} g^{-1}), and 1.6fold in the hyphosphere relative to ambient plots. NAG is an enzyme involved in the degradation of chitin, releasing absorbable forms of nitrogen. The activity of peroxidase, which supports the breakdown of lignin, increased significantly in the hyphosphere of stands exposed to elevated CO_2. Our results may indicate that, while hyphal-derived C shifted the metabolism of the microbial community to C decomposition, accelerated root exudation shifted the community to the decomposition of organic N under elevated atmospheric CO_2. In a next step we will use modelling approaches to upscale our results from soil microsites to the ecosystem level.

Influence of soil temperature and water content on fine-root seasonal growth in beech forest

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Abstract

In tree species fine-root growth is influenced by the interaction of environmental factors such as soil temperature and soil moisture. Studies evidences suggest that if soil moisture and nutrient availability are adequate, rates of root grow increase with increasing soil temperature up to an optimal temperature and then decline at supraoptimal temperatures. These optimal conditions vary among different *taxa* and depend partly on the native environment. Perennial plants exhibit: 1 a strong fine-root seasonal pattern, increasing in early spring and peaking in late spring to mid-summer before decreasing in the fall; 2 species-specific morphological adaptations in response to variation in soil conditions; 3 different dynamics among different fine-root diameter classes. Therefore, the responses of fine roots to soil temperature (ST) and water content (SWC) in natural conditions are still today difficult to demonstrate and to explain at global level. We investigated the effects of seasonal changes of both ST and SWC on very-fine (d < 0.5 mm) and fine roots (0.5 < d < 2 mm) mass (vFRM, FRM) and length (vFRL, FRL) in an Italian Prealps Beech forest (*Fagus sylvatica* L.). Root samples were collected by a soil core method. Mean annual vFRM and FRM were 37.8 g m^{-2} and 122.5 g m^{-2}, respectively; mean annual vFRL and FRL were 1536.5 m m^{-2} and 327.2 m m^{-2} respectively. Mean annual very-fine (vF SRL) and fine (F SRL) specific root length was 41.3 m g^{-1} and 2.9 m g^{-1} respectively. Examined fine-root traits and both diameter classes displayed a complex pattern peaking in summer when SWC was around 40% and ST was around 14 °C. Above this temperature, under almost constant SWC, all fine-root traits declined. All fine-root traits, with exception of SRL, showed significant relationship ($P < 0.05$) with SWC for both diameter classes. Soil temperature showed a significant relationship only with vFRM and vFRL, the latter only within the temperature range between 12 and 16 °C. Plotting soil temperature, water content and very fine-root biomass on a three axis graphic allowed delineating the relative optimal soil environmental characteristics for root growth in our Beech forest. In conclusion, these results suggest that fine-root seasonal fluctuation is tightly related to soil characteristics. SWC seems to be crucial for root development although in our case never decreased below 30% throughout the growing season. Moreover, our findings confirmed the hypothesis that if soil water content is adequate, fine root growth increase with increasing soil temperature up to an optimal temperature range. This was particularly evident at very fine roots scale, highlighting the key role played in seasonal growth.

Analysis of live and dead fine roots of *Chamaecyparis obtusa* using VIS-NIR images

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Abstract

It is important to improve our knowledge on production and turnover rates of fine roots for better understanding of carbon and nutrient dynamics in forest ecosystems. To estimate production and turnover rates of fine roots, biomass of live and dead fine roots were often measured separately. In those studies, live roots were usually distinguished from dead ones by criteria such as colors and resilience of the roots, which were judged by visual or manual inspections. Since the visual or manual inspections could be affected by workers' experiences or handling errors, the processes of live/dead separation could be a cause of uncertainty in estimating production and turnover rates of fine roots. Therefore, we have tried to establish a new technique using visible (VIS) and near-infrared (NIR) spectral images, which was so far successfully applied to examine growth stage and live/dead status of fine roots of poplar seedlings grown in a rhizobox system (Nakaji et al. 2008). However, there is only limited information on availability of the VIS-NIR spectral images for analyses of fine roots of other tree species or those obtained by field sampling. In this study, therefore, we are trying to examine live/dead status of fine roots of 35-year-old *Chamaecyparis obtusa* using the VIS-NIR spectral images. The reflectance images of fine roots were obtained in wavelengths at 600, 700, 800 and 905 nm using a multi-band image scanner (iMeasure Inc., Nagano, Japan) and the balance of the reflectance among four wavelengths were analyzed. Our preliminary results suggested that the analyses of the VIS-NIR images well recognized live/dead status of fine roots for root tips (1st-order roots). However, live roots at second- or higher-orders were often classified erroneously as dead. In the presentation, advantages and problems of this method will also be discussed.

Reference

Nakaji et al. (2008) Plant Soil 310:245–261

The effects of elevated soil temperatures on ectomycorrhizal community and litter decomposition in a Sitka spruce forest in Iceland

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Abstract

Introduction

ForHot is a new research project, studying the effects of increased soil temperature on forest and grassland ecosystems. The setup of this project is unique, due to soil warming as the results of a shift in geothermal area after earthquakes in 2008. Belowground channels of naturally hot water at different soil depths create soil temperature gradients, ranging from +0°C to >+35°C, which is an optimal condition to study ecosystem responses to the warming. In this poster we will present preliminary results on the effects of increased soil temperature on litter decomposition and ectomycorrhizal (ECM) abundance and diversity in a 45 year old Sitka spruce (*Picea sitchensis*) forest.

Litter decomposition

A litter decomposition of Sitka spruce needle litter was assessed by placing mesh bags with the needle litter on top of the soil and harvesting them with regular interval over a one year period. Two different types of litterbags were used; one with 200μm and the other with 5mm mesh size, to isolate the effects of soil fauna on litter decomposition. The changes in needle litter mass were calculated and the decomposition rates at different temperatures were compared.

The heat increment in soil increased the litter decomposition, especially in coarse bags, indicating that soil fauna plays an important part in the decomposition as the heat increases.

Ectomycorrhizae

Preliminary results on the effects of increased soil temperature on ECM were obtained by studying ECM root tips on spruce roots from natural soil samples and the growth of fungal mycelium into mesh bags in the forest topsoil. The amount and diversity of fungal mycelia in bags was assessed. Similarly, the mycorrhizal root-tips were counted and classified, based on morphological characteristics.

The results from both root tips and mesh bags indicate that the density of ECM decreases as heat increases but the heat increment does not affect number of morphotypes. However, some changes in ECM community structure occurred.

Effect of sub-vegetation, grown under different age's *Eucalyptus* plantation, on plant and soil N and C accumulation

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Abstract

Soil management practices have significant impact on soil and crop nitrogen (N) and carbon (C) dynamics. The aim of study was to determine sub-vegetation C and N storage under different ages (5, 7 and 10 year old) Eucalyptus (*E.camaldulensis*) plantations. The research was conducted in 2009 at the East Mediterranean Forestry Research Institute in Tarsus-Turkey. For each Eucalyptus tree age, sub-vegetation species were sampled from $1m^2$ squares, replicated five times. Soil samples were taken from 0–20 cm depth. Plant shoot parts were separated from roots and washed with distilled water and then dried. Dry shoot and root dry weight were determined. C and N concentrations of plant tissues were determined by the dry combustion method at 900°C using a C and N elemental analyzer (Fisher, 2000). The soil organic carbon (SOC) concentration was obtained by subtracting soil inorganic carbon (SIC) from total C.

Sub-vegetation shoot dry weight (SDW) increased with Eucalyptus age. Plants grown under 5 year old Eucalyptus plantation produced 4.22g m^{-2} SDW, under 7 years 6.17g m^{-2} and under 10 years this was 6.21 g m^{-2}. However root dry weight (RDW) did been increase with eucalyptus age. Since the 7 year old plantation suffered from water flooding (from time to time) both roots from sub-vegetation and eucalyptus were well developed. So, plants in this area had shallow roots.

Sub-vegetation sampled from 7 and 10 year old eucalyptus stands has higher C % and N % concentrations than that from 5 year old eucalyptus stands. Shoot and root tissue have higher C and N concentration than root tissue parts. Shoot total N and C accumulation were calculated and plants grown under 5, 7 and 10 years old eucalyptus accumulated 145.8, 217.1, 238.1 ton C ha^{-1} respectively. The total root carbon accumulations were 130.1, 120.7 and 160.5 ton C ha^{-1} respectively. N and C accumulation was directly affected by the longevity of sub-vegetation grown under eucalyptus trees. Since some of the plants are long lived during the preservation they accumulated more dry matter and consequently more C accumulated (P<0.02). Also statistically there is a strong correlation between C and N concentration and accumulation between the measured parameters.

At harvest SOC and N concentration were determined and SOC concentration increased with the sub-vegetation plant age. Soils under 5 years old eucalyptus have 1.69 % of SOC and this increased respectively to 2.40 % and 3.56% under 7 and 10 years old Eucalyptus. SOC and N accumulation in 0–20 cm depth were calculated. This showed that total N accumulation in the Eucalyptus forest soils varied from 6.05, 4.16 and 6.96 ton ha^{-1} with respect to stand ages of 5, 7 and 10 years. Soils collected at 5 year old eucalyptus plantations have in total 40.46 ton ha^{-1} SOC. For respectively 7 and 10 years old plantations they have accumulated 56.04 and 82.66 ton ha^{-1} of SOC.

The SOC accumulation is strongly dependent on plantation age and thus their duration in the soil. There was more C accumulation under old Eucalyptus plantations than in the youngest Eucalyptus vegetation. Not all SOC and total N is supposed to come from the sub-vegetation, most probably some of it may be coming from Eucalyptus roots and other residues. Additional research is needed to assess the role of each factor on sub-vegetation and soil N and C accumulation.

The genetically determined partition of belowground resources affects the growth performance of Norway spruce

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Abstract

In boreal forests, the functional importance of mycorrhizal short roots of trees is high since they form the interface for water and nutrient exchange. Mycorrhizas use fungal specific enzymes in the mobilization of nutrients from litter and soil organic matter and the mycorrhizal species composition has a major influence on nutrient foraging abilities of trees in nutrient poor boreal soils. We have evidence of intraspecific variation in the root associated ectomycorrhizal community structure among differentially growing Norway spruce (*Picea abies*) clones and among spruce genotypes in general (Korkama et al. 2006). Furthermore, the seedling short root formation is genetically controlled by Norway spruce (Velmala et al. 2013).

In the present study we compared the exoenzyme production of ectomycorrhizal root tips of differently growing spruce seedlings families. We did not find any differences in enzyme production owing to the host genotype or growth performance, indicating that in similar growing conditions, spruce seedlings do not have genotype-driven differences in terms of utilization of certain mycorrhizal fungi in the nutrient uptake. However, the enzyme production varied considerably between ectomycorrhizal fungal species colonizing the roots, especially in the case of N and P solubilizing activities. Consequently the functional diversity of ECM fungi may be more important for the nutrient acquisition of host than the taxonomical diversity of ectomycorrhizal fungi. These results also indicate that the short root formation seems to interconnect with later growth performance of spruce. In long-term perspective, the genetically controlled variation in fine root structures and belowground biomass allocation may result in differences in taxonomical and functional diversities of mycorrhizal fungi. The variation in early root structuring might imply great differences in later growth strategies and in the potential of growing trees to harvest interactions with symbiotic fungi in spatially heterogeneous forest soil. Increasing ECM diversity brings along more functional abilities for the host creating a belowground virtuous circle of accumulating goods in heterogeneous forest soil.

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Presence of Norway spruce roots in soil can alleviate Cd contamination effect on decomposition of cellulose

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Abstract

Abiotic and biotic interactions influence decomposition rate of plant litter in soil. Using a pot experiment we aimed at testing the hypotheses i) cadmium (Cd) contamination inhibit decomposition rate of cellulose in soil and ii) plants (*versus* soil with no plants) mitigate the inhibiting effect of Cd on the decomposition of cellulose. Soils were collected at three Norway spruce (*Picea abies*) dominated forest sites in Estonia. The soils were sieved through 5 mm sieve for homogenisation and equal volumes (1.3 L) placed into 12 x 3 (sites) = 36 pots so that the mineral soil filled 9/10 and the organic soil the top 1/10 of the volume. Norway spruce saplings (2 years old) were planted in half of the pots of each site's soil. Six cellulose sheets of the size 1 x 5 cm (about 0.3 g) were laid between the organic and mineral soil in all pots. The pots were placed at constant temperature of 20 °C and 260 µmol m^{-2} s^{-1} of light (16 h) alternating by dark period (8 h). After two months allowed for the plants to establish Cd as solution of cadmium chloride was added into soil as uniformly as possible, using a syringe. Half of the pots received Cd, at the final concentration of 20 mg / kg soil. Six months after the Cd treatment the plants were dug out, the weight and Cd content measured. The soils were analyzed for soluble C, N, Cd and substrate induced respiration. The residues of the cellulose sheets were cleaned out of soil. Mass loss of cellulose was calculated as the ratio of final ash-free dry mass to the initial mass. The results showed from 76% to 100% mass loss of cellulose. In the soil from one site the decomposition rate of cellulose was more than twice greater in Cd-free pots than in the pots treated with Cd, supporting our hypothesis of the inhibiting role of Cd. In the Cd-enriched soils at the presence of Norway spruce saplings the decomposition of cellulose was 1.4 times greater than in the pots with no plants, supporting the hypothesis of mitigating role of plants. The Norway spruce saplings took up a remarkable amount of Cd from the soil during the experiment, thus alleviating the effect of Cd on soil processes. However, in the other two soils the results of the mass loss of cellulose were more variable and the average mass loss (95%) even greater than in the first soil (84%). The difference between sites can partly be explained by greater organic matter content in the first soil (11%) compared with the other two soils (7% and 6%), while the pH was 4.0 to 4.7 in all soils. The results suggest that decomposition of cellulose-rich litters in forest soil can be favoured at the presence of plants (roots) and the contamination effect of Cd on soil microbial processes alleviated. However, the site-specific soil conditions are to be considered.

Effects of LED lighting on seedlings growth of *Fraxinus ornus* L.

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Abstract

In this study we identified the effects of LED light spectra such as G2, AP67, AP67-ARCH, NS2 (Valoya) or Fluorescent light (FL) on seedlings of manna ash (*Fraxinus ornus* L.) on growth and seedling quality. LEDs used emitted a continuous spectrum thanks to a mixture of ultraviolet (radiation subtype C), blue, green, red, far-red and infra-red in various percentages, G2 (B: 7.6% G: 2.4% R: 63.6% FR: 19.5% INFR: 6.8%), AP67 (B: 12.7% G: 15.8% R: 52.7% FR: 13.9% INFR: 4.7%) AP67-ARCH (B: 15.7% G: 25.2% R: 44.8% FR: 10.6% INFR: 3.6%) NS2 (UVC: 1.8% B: 22.3% G: 40.6% R: 33.1% FR: 1.6% INFR: 0.5%).

Seeds of *Fraxinus ornus* were collected in 2011 from Vertiskos mountain at 480 m a.s.l . Seeds after a 24-hour hydration were cold stratified for a 3-month period at 3–50C and placed in phytotron chamber till germination. The pre-germinated seeds was placed in mini-plug trays (QPD 104 QuickPot by HerkuPlast-Kubern, Germany) of identical dimensions (104 cells; 33X33X45 mm; 40 mm/h; 27 cc), filled with stabilized peat (Preforma PP01, Jiffy® Products, Norway), to environmentally con¬trolled growth chambers (14 h photoperiod, 150 μmol m^{-2} s^{-1} PPFD, 70% RH and a 22°C/18°C day/night temperature). Watering was applied twice a day by automatic sprinklers.

After 5 weeks, shoot height under the G2 and FL light was found significantly higher only compared to the NS2 light, while no differences were observed in root lengths among light spectra, although the root length was double in comparison to the shoot length. Adjustments on the morphological state of *F. ornus* seedlings responded relatively to time and light treatment. In particular number of leaves found significantly higher under the AP67 and G2 lights compared to FL, also AP67 differ significantly from the AP67-ARCH light at the 2nd week. At the 5th week significant differences were found only for the G2 light compared to the FL and NS2. Leaf color significant differences become obvious from the 3rd week of the experimental period, where seedlings under FL, AP67 and NS2 lights had dark-green leaves only compared to the light-green ones under the AP67-ARCH. Height growth rate differences are explained by the difference of G2 and FL compared to AP67, AP67-ARCH and NS2 light treatments after the 2nd and 3rd week. The dry weights (leaves, shoot, roots,) were greatest for the seedlings cultured under LEDs and lowest under fluorescent tubes. The R/S ratio was significantly lower under the FL light compared to AP67-ARCH, NS2 and AP67 LEDs. In conclusion our results indicate that raising seedlings under LED lights promoted the optimal growth traits of ash seedlings by means of the whole plant dry weight matter that is an attribute of a great importance regarded it as planting stock material.

The impact of afforestation on the carbon stocks of soils is not as important as accurate accounting

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Abstract

There is a general perception that forest soils would store more carbon than grassland soils. Within the forest ecosystem, soils contain approximately two-thirds of the C stored. The residence time of stable fractions of SOC (soil organic carbon) can be > 1000 years making it a much more stable sink than living plant biomass. This has been reflected in Kyoto protocol and IPCC measures. It is therefore vital to measure the change in SOC stocks following afforestation and to determine the mechanisms involved in controlling SOC dynamics.

The change in soil C following afforestation is controlled by a number of factors: previous land use (grasslands, cropland etc); tree species; soil cultivation method; soil properties (clay content); stand age; site management; topography; climatic zone and methodological approaches. After peat forestry (42%), the largest proportion of Irish forests are on gley soils (25%), with high clay content which leads to increased physical protection of organic matter. "Kyoto forests" are more likely to be on gley soil rather than peat in the Irish context.

The objectives of this paired plot study were: (1) to quantify the carbon stored in the forest floor and soil (0–50 cm) of 52 forest sites and their adjacent non-forest site on same soils; and (2) to assess the impacts of afforestation on soil carbon stocks using the paired plot method.

Analysis shows that, on average, carbon is not sequestered at a significantly higher rate in forest soils (mean difference was 4.245 t ha^{-1} (t=1.28, p=.20), not significant) but that there are expected differences between soil and forest types related to environmental factors. This result indicates that soil C stocks are not affected significantly by litter resource quality but that biological and environmental controls predominate in the main and molecular structure alone does not determine SOM stability.

This data would provide a national estimate 61 Tg C in the top 50cm of mineral soils, which indicates that 22 Tg C is in peat forest soils according to previous national estimates of all forests soils of 83 Tg C. In this study peat soil C was measured to actual depths and a regression equation was developed where depth can be used to estimate soil carbon content. It is estimated that the total carbon stock of Irish forested peat is 2100 Tg C. This total is far greater than previous estimates to 1m depth and clearly demonstrates the underestimate in the forested peat stocks and by default the national forest soil C stock even considering the apparent lack of C accumulation on gley/mineral soils.

Extramatrical mycelial space occupation of ectomycorrhizal fungi of beech seedlings grown at different temperature regimes in rhizotrons

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Key-words: Ectomycorrhizal fungi, extramatrical mycelia, long-distance exploration type, space occupation, rhizotrons, belowground temperature

Abstract

Extramatrical mycelia (EMM) of ectomycorrhizal fungi differ in their density, organization and extension (Agerer and Raidl, 2004). With respect to differences in EMM, Agerer (2001) distinguished five exploration types (ET), presumably also differing in their role in water and nutrient uptake and translocation (Wallander et al, 2010). In our study the impact of temperature on EMM of long-distance ET (*Scleroderma* sp.) of beech seedlings (*Fagus sylvatica* L.) grown in rhizotrons was investigated. Seedlings were grown for three years in glass rhizotrons (30x50x2 cm) in a temperature controlled walk in growth chamber at 15–20° C without additional cooling of root systems (NHL) and at 15–20° C with an additional cooling of the root systems for 4° C (DHL). Rhizotrons were photographed monthly using a digital camera (CANON EOS 450D) and analysed with Adobe® Photoshop® CS3 Extended (Adobe Systems). We found significant differences of EMM space occupation between treatments in May 2010, January 2011 and January 2012. In NHL the EMM networks were better developed in May 2010 and January 2011 than in DHL, while in January 2012 the EMM space occupation were greater in DHL. In both treatments changing of space occupation was observed between years: in May 2010 the EMM space occupation was the least of all, in January 2011 it increased and in January 2012 it was reduced again. Our results have shown an effect of temperature in root environment on EMM space occupation of ECM fungi, which can influence functioning of the common mycorrhizal networks in differently disturbed forest ecosystems.

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