



Carbon partitioning in a wet and a semiwet subarctic mire ecosystem based on in situ ^{14}C pulse-labelling

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ABSTRACT

In this study we quantify the partitioning of recent assimilates to above- and below-ground carbon (C) pools in two subarctic mire ecosystems – wet minerotrophic and semiwet ombrotrophic mire – using in situ ^{14}C pulse-labelling. Ecosystem C partitioning to rhizomes, coarse roots, fine roots, dissolved organic carbon (DOC) and microbes were quantified twice during the growing season at three different soil depths. Finally the ^{14}C -partitioning data from this and a previous study were combined to estimate the overall C partitioning of the three main vegetation types of a Scandinavian subarctic mire in early and late summer.

The semiwet ombrotrophic ecosystem hosted a much larger root biomass on an area basis compared to the wet minerotrophic ecosystem which might be due to differences in the soil nutrient level. Microbial C was found to be the largest C-pool in both ecosystems. Ecosystem ^{14}C partitioning was poorly related to plant biomass for the semiwet and the wet ecosystem. Overall a higher partitioning of recent assimilates to below-ground compartments was apparent in August–September compared to June–July, while the opposite was found for the above-ground C-pools. In the semiwet ecosystem twice as much ^{14}C was found in DOC compared to the wet ecosystem, where root density, litter and above-ground biomass were important controls of the ^{14}C -recovery in DOC. Plant-derived DOC was estimated to be 15.4 versus 12.9 mg C m⁻² d⁻¹ in the semiwet and wet ecosystem, respectively.

Graminoid dominated and dwarf shrub dominated vegetation types of the subarctic mire Stordalen differ with respect to the relative amount of recently assimilated C partitioned to C-pools with “slow” versus “fast” decomposition rate. The capacity for sequestration of recently fixed C within “slow” C-pools might affect the ecosystem C balance (NEE) and C-storage. The potential for vegetation changes might therefore be an important factor to consider in studies of response of ecosystem C-dynamics to global change factors in subarctic mires.

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1. Introduction

Carbon partitioning is an important ecosystem process distributing assimilated photosynthates between short- and long-lived tissues, below-ground and above-ground compartments but also respiration and biomass production. Changes in the C partitioning can affect the distribution of plant biomass as well as the ecosystem biogeochemistry when C is invested in tissues with different litter quality and decomposition rates (Hobbie, 1996; Litton et al., 2007). If C is stored in, for example, long-lived coarse roots this will sequester atmospheric CO₂ for longer time scales. An understanding of ecosystem C partitioning is therefore essential for predicting how

C-fluxes between the atmosphere and the terrestrial biosphere will change in response to global warming. In total, arctic and boreal soil C-pools represent c. 30% of global soil C, making these regions a major potential source of atmospheric CO₂ in a changing climate (Post et al., 1982). Northern mires in subarctic and arctic regions underlain by permafrost are comparable in structure and function and contain a significant proportion of this C.

Plant C partitioning is affected by environmental parameters, including resource availability and temperature (Friedlingstein et al., 1999), and plants adjust their C distribution pattern to maximize growth (Tilman, 1988). In order to predict how ecosystem C partitioning responds to environmental change process-based terrestrial ecosystem models are developed. C partitioning coefficients are used by ecosystem models in order to determine the proportion of assimilated C that a compartment receives. In order to calculate such coefficients all components of

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the C budget should be determined. This study aims at contributing with a quantified insight into C partitioning in two dominating vegetation types of a northern mire.

Northern mire plants are known to have large proportions of their biomass situated below-ground. Root:shoot ratios in mire and tundra vegetation are well documented and range from 5 to 45, depending on species composition and soil nutrient levels (Dennis and Johnson, 1970; Wielgolaski, 1972; Shaver and Chapin, 1991). Plant C partitioning below-ground varies spatially, but also temporally, with different relative amounts of C entering different C compartments, such as living plant tissues, microbes and DOC, over the season (Saggar and Hedley, 2001). This will affect the chemical composition and turnover rate of C compounds produced on the mire and consequently the total ecosystem C balance (Saggar and Hedley, 2001; Loya et al., 2004). It has been shown that recent decades warming in the subarctic may have led to thawing of permafrost with subsequent changes in the vegetation composition (Christensen et al., 2004; Schuur et al., 2009). On Stordalen mire wet and semiwet areas has been shown to increase compared to dry areas over a 30 years period (Christensen et al., 2004). Changes in plant community structure and composition associated with future warming will most likely have implications for C-cycling in tundra and northern mire soils since different ecosystems store different amount of C into slowly and fast decomposing litter. Certain types of litter produced, such as litter from mosses, will be stored on a longer time scale while litter from fine roots will turnover faster (Gill and Jackson, 2000). Hobbie (1996) showed that differences in rates of litter decomposition among species were sometimes greater than differences between warming treatments and controls applied to the same species. However, differences in C compartment quality also imply that individual pools will respond to climate warming in different ways (McLaugherty et al., 1985; Nadelhoffer et al., 1991; Hobbie, 1996). In this study we are working with biomass, i.e. C-pools and ^{14}C partitioning to different components of the ecosystem. According to Litton et al. (2007) biomass is the amount of material present and partitioning is the fraction of gross primary productivity (GPP) used by a component. Hence, ecosystem ^{14}C partitioning gives an instant or short-term picture of the C transport to different parts of the ecosystem while amount of biomass reflects the long-term transport of C to an ecosystem compartment.

In this study we quantified the partitioning of recent assimilates to above- and below-ground C-pools in two Scandinavian subarctic mire ecosystems – wet minerotrophic and semiwet ombrotrophic mire – using in situ ^{14}C pulse-labelling. By combining data from modelled and instantaneously-measured CO_2 flux data, ^{14}C lost as respired CO_2 was also quantified. Since a great part of assimilated C is transported below-ground in mire ecosystems (Shaver and Chapin, 1991), a more detailed study of below-ground C partitioning was done. Plant C partitioning to coarse roots, fine roots and incorporation of C into microbes and dissolved organic C (DOC) was quantified for two occasions during the growing season. Furthermore, repeated DOC sampling made it possible to quantify the plant originated DOC production. The results of this study, together with results of Olsrud and Christensen (2004), will give an example of C partitioning above- and below-ground in the main subtypes of a Scandinavian subarctic mire ecosystem.

We hypothesized that the ecosystem C partitioning would change with season, soil depth and ecosystem type. For example, below-ground C partitioning would be higher in the ombrotrophic semiwet ecosystem compared to the wet minerotrophic ecosystem due to differences in the soil nutrient content. We also hypothesise that different ecosystem types would contribute differently to C-storage of the mire, where wet ecosystems store more C into slowly decomposing compartments such as mosses and rhizomes

compared to the dry ecosystem that partition a high proportion of C to delicate structures such as hair roots turning over fast.

2. Material and methods

2.1. Study site and setup

The study was carried out at two separate time periods during the 2002 growing season, i.e. 17/6–18/7 (June–July) and 24/8–24/9 (August–September), in a subarctic mire (Stordalen) 341 m a.s.l. 10 km east of Abisko in northern Sweden (68°21'N, 19°00'E). At Abisko weather station the mean annual temperature is $-0.8\text{ }^\circ\text{C}$ while the warmest month's average temperature is $11.0\text{ }^\circ\text{C}$. Average annual accumulated precipitation (1913–1999) is 300 mm. The Stordalen mire is a 25 ha large peatland of the eastern continental type in northern Scandinavia. The mire consists of elevated ombrotrophic parts that alternate with minerotrophic parts, i.e. lower hollows and depressions characterised by nutrient-richer conditions and, hence, a different species composition (Sonesson and Kvillner, 1980). The study was carried out at two separate sites encompassing two vegetation types: (1) semiwet ombrotrophic parts dominated by *Carex rotundata* and *Sphagnum balticum*; and (2) wet minerotrophic parts dominated by *Eriophorum angustifolium*. The wet minerotrophic areas of the mire receive its abundant flow of water from the surrounding drainage area in addition to direct input from precipitation. The semiwet ombrotrophic areas, on the other hand, receive its major input of water from precipitation and are hence less nutrient rich. At each site a total of 10 plots were positioned at least 0.7 m apart within an overall area of approximately 225 m². Each plot consisted of an aluminium base inserted 10–20 cm into the ground, enclosing 22 × 22 cm of vegetation, representative for the study site. The plots were used for CO_2 flux measurements and ^{14}C -partition measurements (see below).

Soil temperature was logged at 5 cm soil depth every 15 s at three points within the semiwet ecosystem between 1 April–6 October using thermocouples and a CR10-X data logger (Campbell Scientific Ltd., Shepshed, UK). These temperature measurements were also applied to the wet ecosystem.

2.2. CO_2 fluxes and regression models

Respiration measurements in the plots were performed on 12 occasions during the season, 6 times each during the period June–July and August–September. A standard closed-chamber technique was employed similar to that described by Christensen et al. (2000). Ecosystem CO_2 fluxes were measured using an infrared gas analyser (IRGA) (EGM-2, PP-Systems, Hitchin, UK) coupled to the chamber with an internal 12 V fan. The aluminium bases were equipped with a water-filled channel that ensured an airtight seal between the airtight plexi-glass chamber and base. Respiration was measured by installing a darkened plexi-glass chamber on the aluminium base and then measuring the change in CO_2 concentration within the chamber during the course of 30–90 min. The CO_2 concentration inside the chamber typically approached a concentration of 700 ppm.

Regression analysis (SPSS 10.0) was applied to derive models describing how respiration varied with soil temperature in the semiwet ombrotrophic ecosystem (Fig. 1a) and the wet minerotrophic ecosystem (Fig. 1b).

2.3. $^{14}\text{CO}_2$ -Labelling

Five plots in each ecosystem were randomly selected and pulse-labelled with 8–14 MBq $^{14}\text{CO}_2$ each using the method described by

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