

# Carbon stocks and carbon fractions in the organic layer (F + H) of forest soil

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Recent studies have demonstrated that there is a clear link between climatic variability and the carbon balance in boreal and temperate forest ecosystems and soils (Qualls et al. 2003, Guo et al. 2005). The interaction between climate warming and carbon pools in forest soils at high latitudes may be important because climate change is expected to be the greatest in northern boreal and especially sub-Arctic and Arctic regions (Vucetich et al. 1999). The formation of relatively inert humic substances may have an influence on the processes controlling the recycling of soil carbon back to the atmosphere (Qualls et al. 2003).

The build up of soil organic matter (SOM) depends on the amount of litter produced, the chemical composition of the litter, the rate of decomposition and the mechanisms controlling it, and climatic factors (Berg et al. 1995, Berg et al. 2001, Vejre et al. 2003). When the same kind of vegetation is growing for a long time on the same site, a state of equilibrium is reached between the input of litter and its rate of decomposition in the soil. This leads to the formation of an organic layer containing an amount of organic matter that is relatively typical of the site in question (Evans et al. 2005).

The chemical composition of plant litter varies between and within species. Litter from the same species, but growing on different types of site, may have a very different mineral content and composition of organic substances such as lignin, cellulose and nitrogenous compounds (Howard and Howard 1980). Differences in the proportions of the individual chemical fractions of litter may lead to marked differences in organic matter accumulation in the soil (Berg et al. 2001), as well as strongly affecting N and C dynamics in the soil (Côte et al. 2000).

Soil organic matter consists of a wide range of carbon compounds in a varying degree of decomposition (e.g. water-soluble carbon fractions, humic substances etc.) (Ryan et al. 1990, McTiernan et al. 2003). The organic compounds in decomposing litter can be divided into three main groups: 1) non-polar extractives (waxes, fatty acids and lipids) and water soluble compounds (e.g. sugars and phenolics) 2) slowly decomposing polysaccharides (e.g. cellulose and hemicellulose), and 3) relatively inert, acid-insoluble aromatic compounds (e.g. lignin). The last group contains a wide range of compounds that vary among species and litter types. For this reason, the rate of decomposition of these organic compounds, and their effect on carbon and nutrient cycling, varies considerably (Ryan et al. 1990).

## The main aims of the study were:

1. To determine the magnitude of the carbon stocks in the organic layer (F and H layers) of Scots pine (VT forest site type) and Norway spruce (MT, OMT) stands.

2. To determine the proportions of water-soluble, slowly decomposing and relatively inert chemical fractions in the fermentation (F) and humus (H) layers in pine and spruce stands.
3. To determine whether there are differences in the carbon concentration of the organic layer in pine and spruce stands in northern and in southern Finland.
4. To determine the amount of carbon in the roots and rhizomes in the F and H layers (data not shown here).

## Material and methods

Eleven of the sites sampled in this study are a part of the ICP Forests (UN/ECE)/Forest Focus (EU) intensive monitoring plot network, and one site is the control plot of a fertilization experiment established in a spruce stand by Metla in Sodankylä. The plots are situated in Tammela (MT, VT), Juupajoki (OMT, VT), Punkaharju (OMT, VT), Kivalo near Rovaniemi (HMT, EMT), Pallasjärvi (HMT, EMT) and Sodankylä (HMT, EMT).

Samples of the ground vegetation and organic layer were taken in 2002 and 2003. Twenty eight sample squares (30 cm x 30 cm) were taken systematically from each of the 12 stands. Each sample square included all the living vegetation and the underlying organic layer. The organic layer was divided into the L (litter layer), F and H layers. The total area of the sample squares on each plot was 2,52 m<sup>2</sup>. The coverage of plant species and litter was assessed visually before the sample square was taken.

Identifiable roots and rhizomes were separated from the samples. The soil samples were dried (60°C) and then milled to pass through a 1 mm sieve. The ash content of the samples was determined by burning in a muffle furnace at 550°C for 2 hours. The milled samples were analysed using a sequential extraction technique according to Ryan et al. 1990.

The organic matter content of the samples was determined as the loss in weight on ignition at 550°C. Total C and N concentrations were determined on an automatic CHN analyzer.

## Results

According to the preliminary results:

- The total C content as well as individual carbon fractions were higher in the H than in the F layer when all visible roots and rhizomes are excluded (Fig. 4.)
- More C has accumulated in the F and H layers in the Norway spruce than in the Scots pine stands.
- The amount of cellulose and humic substances are higher in the Norway spruce stands compared to Scots pine stands (Fig. 4.)
- In the F and H layers the concentration of polar and nonpolar extractives are higher in spruce stands than in pine ones.
- The total N concentration (results not shown here) is higher in the F layer of the pine and spruce stands compared to the H layer.

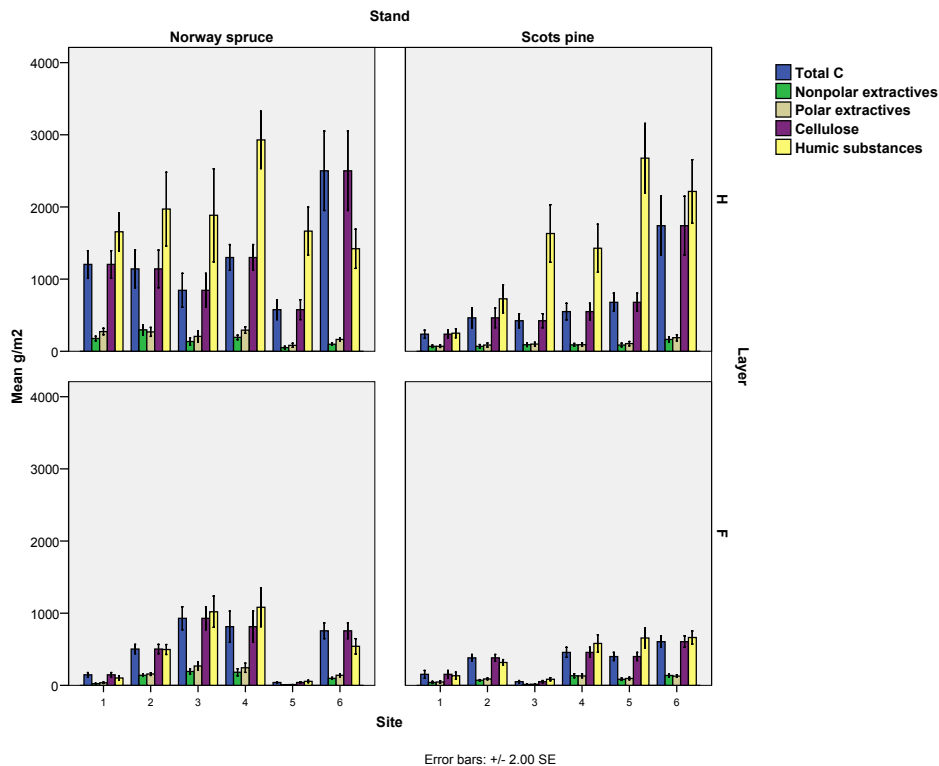


Fig. 4. The amount of total C, nonpolar extractives, polar extractives, cellulose and humic substances in F and humus layers of sample stands. Site 1= Pallasjärvi, 2 = Sodankylä, 3 = Kivalo, 4 = Punkaharju, 5 = Juupajoki and 6 = Tammela

## References

- Berg, B., McClaugherty, C. Virzo De Santo, A., Johansson, M. B. and Ekbohm, G. 1995. Decomposition of litter and soil organic matter – Can we distinguish a mechanism for soil organic matter buildup? *Scandinavian Journal of Forest Research* 10: 108-119.
- Berg, B., McClaugherty, C., Virzo De Santo, A. ja Johanson, D. 2001. Humus buildup in boreal forests: effects of litter fall and its N concentration. *Canadian journal of Forests Research* 31: 988 - 998
- Côte, L., Brown, S., Parre, D., Fyles, J. and Bauhus, J. 2000. Dynamics of carbon and nitrogen mineralization in relation to stand type, stand age and soil texture in the boreal mixedwood. *Soil Biology and Biochemistry* 32: 1079 -1090.
- Evans, H., Fernandez, I., J., Rustad, L., E. and Norton, S., A. 2001. Methods for evaluating carbon fractions in forest soils: A review. *Technical bulletin* 178: 4 - 42.
- Guo, L. B. , Halliday, M. J., S. Siakimotu ,J. M., et al. Fine root production and litter input: Its effects on soil carbon. *Plant and Soil* 272: 1 - 10.
- Howard, D. M. and Howard, P. J. A. 1980. Effect of species, source of litter, type of soil, and climate on litter decomposition. *Microbial decomposition of tree and shrub leaf litter* 3. *Oikos* 34: 115 -124.
- McTiernan, K. B., Coûteaux, M.-M., Berg, B., Berg, M.P., Calvano de Anta, R., Gallardo, A., Kratz, W., Piussi, P., Remacle, J., Virzo De Santo, A. 2003. Changes

- in chemical composition on *Pinus sylvestris* needle litter during decomposition along a European coniferous forest climatic transect. *Soil Biology and Biochemistry* 35: 801-812.
- Qualls, R. G., Takiyama, A. and R Wershaw, R. L. 2003. Formation and loss of humic substances during decomposition in a pine forest floor. *Soil Science Society of American Journal* 67: 899 - 909.
- Ryan, M. G., Melillo, J. M. and Ricca, A. 1990. A comparison of methods for determining proximate carbon fractions of forest soils. *Canadian Journal of Forest Research* 20: 166 - 171.
- Vejre, H. Callesen, I., Vesterdal, L. and Raulund-Rasmussen, K. 2003. Carbon and nitrogen in Danish forest soils contents and distribution determined by soil order. *Soil Science Society of American Journal* 67: 335 - 343.
- Vucetich, J.A., Reed, D.D., Breymeyer, A., Dego' rski, M., Mroz, G. D., Solon, J., Roo-Zielinska, E. and Noble, R. 2000. Carbon pools and ecosystem properties along a latitudinal gradient in northern Scots pine (*Pinus sylvestris*) forests. *Forest Ecology and Management* 136: 135 -145.