# Carbon dynamics for a drained peatland forest with drainage and nutrition gradients

M. Hartman[1)], M. Karsisto[1)] and S. Kaunisto[1)]

[1)] The Finnish Forest Research Institute, Vantaa Research Centre, P.O. Box18, 01301 Vantaa, Finland. markus.hartman@metla.fi

## Abstract

The carbon balance of pristine and drained boreal peatlands is one of the focal points of ecosystem research. Usually drained peatland forests are considered carbon sinks. However, on some site types the tree stands may suffer from nutrient imbalances. We present a hypothesis of the carbon balance of a drained peatland forest. The treatments of the experiment are control and NPK-fertilization. The estimates of the autotrophic and heterotrophic $CO_2$-C-respiration fractions were based on the tree stand biomass and literature data.

The NPK treatment had resulted in enhanced tree growth and stand. On most control plots the tree stand and growth were smaller and the concentrations of P and K in the pine needles were low. The range of the $CO_2$-C respiration was roughly the same on both the fertilized and unfertilized plots. The estimated autotrophic fraction was higher on the NPK treatments while the hetrotrophic was higher on the controls.

## 1. Introduction

The carbon (C) balance of boreal ecosystems and especially on pristine and drained peatlands is one of the focal points of current ecosystem research (Alm 1997). Usually peatlands drained for forestry are considered sinks of C (Minkkinen & Laine 1998). After drawdown of the water table the soil respiration is enhanced but, over time, the C accumulation in the tree stand biomass and the root litter outbalances the $CO_2$-C respiration from the peat. On some site types the available peat nutrients (e.g. P and K but also N) limit tree growth and these sites may become sources of C. Nutrient (NPK) application enhances growth and C accumulation of the tree stand. We present a hypothesis of the C dynamics on a drained and forested mire with different drainage and nutrition treatments during a vegetation period.

## 2. Material and methods

The experiment is located on the Liesineva mire in Parkano, western Finland (Huikari 1959). Originally it was a wet, open or sparsely forested mire. The original mire types formed a loose gradient from ombrotrophic to oligotrophic site types.

The mire was originally drained in 1915 with a strip width of 200 m. In the 1950s the drainage was complemented using different drain spacing and drainage technologies (open and covered ditches). Presently the dominant tree species is Scots pine (*Pinus sylvestris* L.), mixed with downy birch (*Betula pubescens* Ehrh.) on some plots. The experiment is laid out in two blocks, block 2 (open ditches) and block 3 (covered ditches). The treatments in each block are control, Co2 and Co3 (n = 5) and repeated fertilization, NPK2 and NPK3 (n = 5). The examined ditch spacings are 20, 40, 60 and 100 m. Peat samples (humus, 0-10 and 10-20 cm) for determination of nutrients and microbial biomass carbon (Martikainen et *al.* 1990) and pine needle samples for determination of needle nutrients (Braekke 1996) were collected from the sample plots. $CO_2$-C respiration from the peat was measured during the vegetation period using the chamber method (Silvola et *al.* 1994). Simultaneously, the ground water level, air temperature and soil temperatures (5 cm) were measured. Based on these observations, plot $CO_2$-C respiration was modelled and the autotrophic and heterotrophic fractions estimated. The autotrophic respiration was estimated on basis of the tree stand biomass, unpublished root biomass estimates from sites treated in a similar way, and data from the literature (Ryan et *al.* 1994). The estimated autotrophic fraction was then subtracted from the total to give the heterotrophic fraction.

## 3. Results and discussion

The peat N and P amounts correlated along the trophic gradient while the peat K remained on the same leve irrespecitve of the peat N and P (Figure 1).

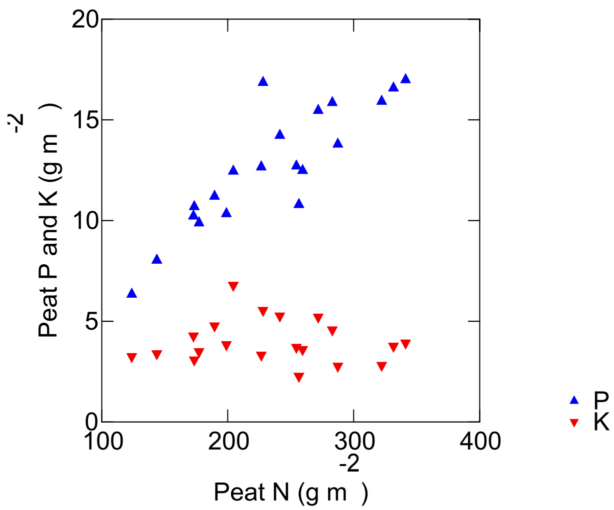


Figure 1. Relationships between surface peat (0-10 cm) P, K and N.

The amount of C in the peat and humus was roughly the same on all plots. The NPK treatment resulted in enhanced tree growth and stand biomass accumulation (Figure 2).

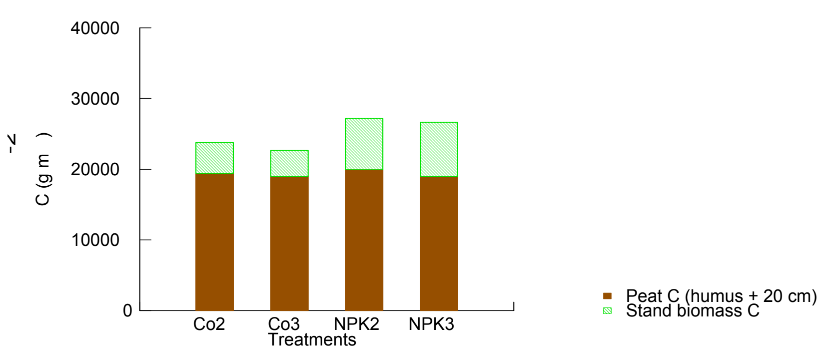


Figure 2. Peat and stand biomass carbon (g d.w. $m^{-2}$) by treatments.

The correlations between the stand biomass C and the needle P (r= 0.65) and K (r = 0.56) were significantly positive, indicating that these elements were growth limiting;

the correlation with the needle N was not significant (r = 0.30). In relation to N concentrations, concentrations of P and K in the pine needles on the control plots were low and indicated limited availability of these nutrients (Figure 3). When the amounts of available peat N is high compared to the available P and K amounts the tree stands may suffer from nutrient imbalances (Veijalainen 1977). Stand growth may be affected and indirectly thus the C balance of the site.

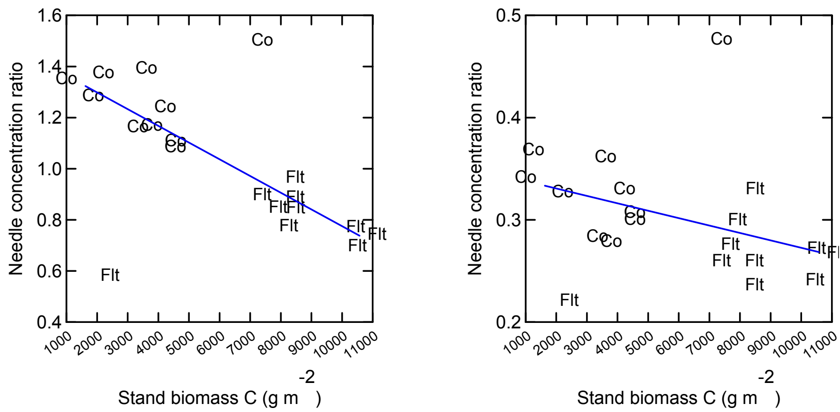


Figure 3. Relationship between needle N:P ratio, needle N:K ratio and tree stand C. Co = Co2 and Co3, Flt = NPK2 and NPK3. The approximate deficiency limits are 1.3 mg $g^{-1}$ for N, 1.4 mg $g^{-1}$ for P and 4.5 mg $g^{-1}$ for K.

The microbial biomass C, which indicates microbial activity, was generally higher on the control plots than on the NPK plots (Figure 4).

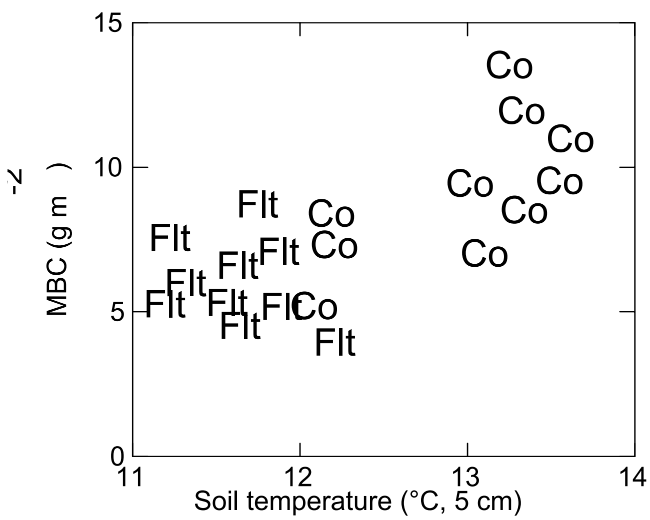


Figure 4. Relationship between mean peat soil temperature and microbial biomass C. Co = Co2 and Co3, Flt = NPK2 and NPK3.

In this experiment, the ditch spacing did not affect the ground water table. The soil $CO_2$-C respiration during the vegetation period related to the fluctuations of the ground water level and soil temperature (Figure 5).

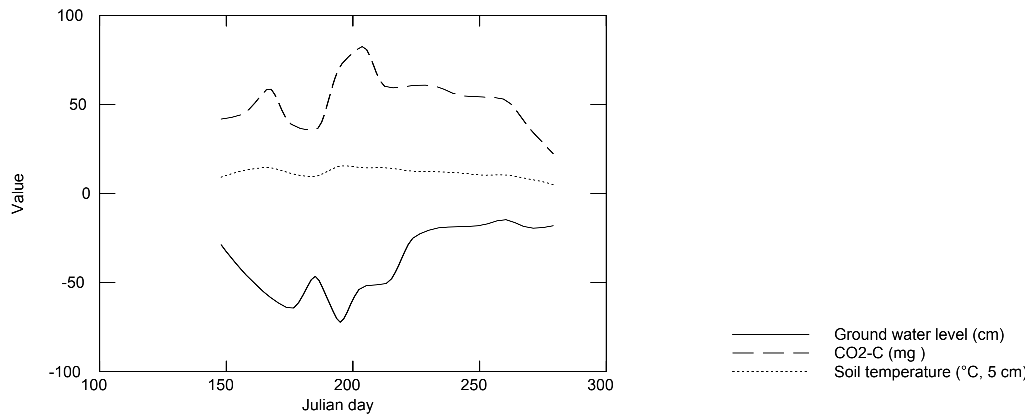


Figure 5. Example of fluctuations of ground water table, soil temperature and $CO_2$-C during the vegetation period on a sample plot.

The range of the $CO_2$-C respiration was roughly the same on both the fertilized and unfertilized plots.

The estimated autotrophic fraction was higher on the NPK treatments while the heterotrophic was higher on the controls (Figure 6).

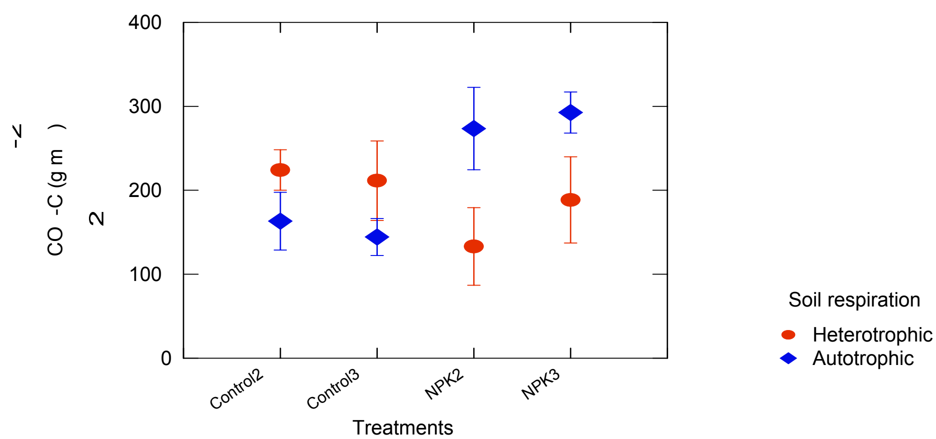


Figure 6. Means and SE of estimated soil respiration fractions by block and treatment.

The results of this study indicate that drained mire sites with nutritional imbalances may be net sources of C. Factor analysis suggests an antagonistic relationship between tree stand and microbial activity (Figure 7).

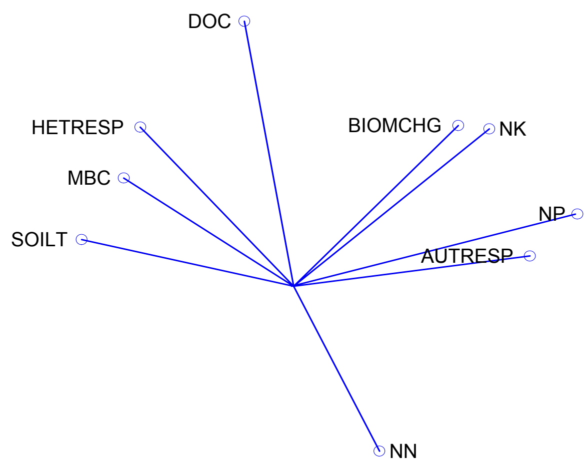


Figure. 7. Factor analysis of relevant tree stand and microbial activity variables. AUTRESP = estimated autotrophic soil respiration ($CO_2$-C), BIOMCHG = stand biomass C change ('growth'), HETRESP = estimated heterotrophic soil respiration ($CO_2$-C), MBC = microbial biomass C (0-10 cm), DOC = dissolved organic C (0-10 cm), NN = pine needle nitrogen, NK = pine needle potassium, NP = pine needle phosphorus, SOILT = mean peat surface (- 5 cm) temperature during measurement period (May – October).

The immediate and long-time effects of nutrient application on the peat, belowground biomass activity and autotrophic vs. heterotrophic respiration should be studied in more detail, particularly regarding aspects of the C balance.

## 4. References

Alm, J. 1997. CO2 and CH4 fluxes and carbon balance in the atmospheric interaction of boreal peatlands. - University of Joensuu. Publications in Sciences, vol 44, 34 p + app.

Braekke, F. H. 1996. Needle analyses of Norway spruce and Scots pine stands. - Trees 11, 23-33.

Huikari, O. 1959. Metsäojitettujen turvemaiden vesitaloudesta. Referat: Über denWasserhaushalt waldentwässerter Torfböden. - Communicationes Instituti Forestalis Fenniae, vol 51, 2, 1-45.

Martikainen, P. J. and Palojärvi, A. 1990. Evaluation of the fumigation-extraction method for the determination of microbial C and N in a range of forest soils. – Soil Biology and Biochemistry, vol 22, 6, 797-802.

Minkkinen, K. and Laine, J. 1998. Long-term effect of forest drainage on the peat carbon stores of pine mires in Finland. - Canadian Journal of Forest Research, vol 28, 1267-1275.

Ryan, M., Linder, S., Vose, J. and Hubbard, R. 1994. Dark respiration of pines. - In: Gholz,H., Linder, S and McMurtrie, R. (eds.). Environmental constraints on the structure and productivity of pine forest ecosystems: a comparative analysis. Ecological Bulletins, vol 43, 50-63. Copenhagen.

Silvola, J., Alm, J., Ahlholm, U., Nykänen, H. and Martikainen P. J. 1994. $CO_2$ fluxes in peatlands under varying temperature and moisture conditions. – In: Kanninen, M and Heikinheimo P. (eds.). 1994. The Finnish research programme on climate change. Second progress report. Publications of the Academy of Finland, 1/94, 273-276.

Veijalainen, H. 1977. Use of needle analysis for diagnosing micronutrient deficiencies of Scots pine on drained peatlands. Seloste: Neulasanalyysi männyn mikroravinnetilanteen määrityksessä turvemailla. - Communicationes Instituti Forestalis Fenniae, vol 92, 4, 1-32.