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THE EFFECT OF WOOD ASH ON SOIL CO_2 EMISSION AND CARBON STOCK OF TREE STAND ON A DRAINED PEATLAND – CASE STUDY

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SUMMARY

Forested peatlands contain large pools of terrestrial carbon. Besides drainage also forest management, e.g., fertilization, can affect these pools. We studied the effect of wood ash application (5 or 15 t ha^{-1}) on the heterotrophic soil respiration (CO_2 emission from the decomposition of peat) on a pine-dominated drained mire in central Finland. The ash was spread 13 years before the measurements. Wood ash roughly doubled the CO_2 emission from the peat soil. Ash treatments increased stand growth substantially: the growing stock on ash plots accumulated carbon 11-12-fold compared to control. In conclusion, the ash induced increase in biomass production considerably decreased carbon emissions from the study site.

KEY WORDS: Drainage, fertilization, wood-ash, greenhouse gas, CO_2 emission, soil respiration

INTRODUCTION

In Finland, more than half from the original 10 million ha of pristine peatlands have been drained for forestry. Several studies have been made concerning on the effects of drainage on the C balance of forested peatland's ecosystem, that is C stock and CO_2 fluxes of soils (e.g. Minkkinen and Laine, 1998; Minkkinen *et al*., 2007; Ojanen *et al*., 2010). However, little is known of the effect of silvicultural management practices on the C dynamics on peatlands.

Wood ash contains many essential nutrients required for plant growth, and can thus be utilized as soil fertilizer especially on phosphorus (P) and potassium (K) poor peatlands (e.g. Silfverberg, 1996). The long-lasting positive effect of wood ash on the growth of conifers in peatlands have been reported in many studies (e.g. Silfverberg and Hotanen, 1989; Moilanen *et al*., 2002, 2005). Thus, it can be expected that also the amount of C sequestered in biomass would increase due to ash application.

Wood ash is noted to decrease peat acidity (e.g. Silfverberg and Hotanen, 1989) and also to increase microbial activity and organic decomposition in peat (e.g. Karsisto, 1979; Weber *et al*., 1985; Moilanen *et al*., 2002). Thus, it is assumed that wood ash also has an effect on soil gas exchange. However, data on the effects of wood ash on peatland CO_2 emission is rather scarce (Maljanen *et al*., 2006; Ernfors *et al*., 2010; Klemedtsson *et al*., 2010).

The objective of this study was to evaluate the effects of wood ash application on soil CO_2 fluxes and amount of C accumulated in tree stand on a drained peatland in central Finland after 13 years from ash fertilization application.

MATERIAL AND METHODS

The study site represented a mesotrophic wooded fen (herb-rich sedge birch-pine fen according to Finnish site type classification, see Laine and Vasander 1996) and started to develop towards forested peatland characterized by dwarf shrubs layer formed by blueberry (Vaccinium myrtillus II forest site type, Vasander and Laine, 2008) after the drainage carried out in the 1950s. The tree stand was dominated by Scots pine (*Pinus sylvestris* L.) accompanied by downy birch (*Betula pubescens* Ehrh.) At the time of ash fertilization, dominant height of the stand was 6–8 m and stand volume about 60 m^3 ha^{-1}. Based on foliar analysis mineral nutrients, especially P and K, were limiting tree growth, whereas the N status of trees was good (Moilanen and Silfverberg, 2004).

The wood ash used in this study originated from pulp mill. The loose (powdered) ash was spread manually in May–June 1997. The applied treatments were 0 (control), 5 t ha^{-1} and 15 t ha^{-1} dry weight. Accordingly, the amounts of added nutrients for Ca was 1750 – 5250 kg ha^{-1}, for K 140 – 420 kg ha^{-1}, for Mg 90 – 270 kg ha^{-1} and for P 45 – 135 kg ha^{-1}.

The effects of ash application on peat heterotrophic CO_2 flux were studied on three treatment plots (size 900 m^2) located close to each other. A systematic grid of 9 measurement plots was established in each of the three treatment plots. Above-ground litter and the above-ground parts of the green plants were removed from the measurement plots before the measurements. The elimination of autotrophic root respiration was done by using the trenching technique. The plots were trenched to a depth of 30 cm using a metal cylinder with the intention of excluding root respiration and further growth of new roots. The soil CO_2 effluxes were measured 20 times in 2008 – 2010 using a closed-chamber system with air circulating in a loop between the chamber and an external infrared gas analyser (IRGA). Soil temperatures were measured and used in modeling the efflux. The parameters for the soil CO_2 emission functions were calculated by applying non-linear regression using least squares loss function with the Gauss-Newton method.

For tree measurements, the trees were counted by species, and the heights (dm) and diameters at breast height (d1.3, mm) were measured from 15–17 sample trees per treatment plot. Increment cores were extracted from sample trees to determine the development of annual radial growth. The development in stem wood volume (m^3 ha^{-1}) in 1995 - 2010 was determined by using the volume functions from Laasasenaho (1982). The stand biomass was calculated using equations from Repola (2009). The amount of carbon bound in the stand’s dry mass was calculated by multiplying the dry mass by 0.52.

RESULTS

Soil CO_2 efflux

Soil annual CO_2 emission was lowest on the unfertilized control plot, 238 g CO_2-C $m^{-2}a^{-1}$ (Fig. 1). The use of wood ash increased the emission by 77 % - 100 % compared to control. The difference between the two ash doses was moderate. Wood ash dose of 15 t ha^{-1} resulted in 13 % higher (475 g CO_2-C $m^{-2}a^{-1}$) annual CO_2 emission than lower dose of 5 t ha^{-1} (420 g

CO_2-C $m^{-2}a^{-1}$). The proportion of the annual CO_2 emission during the wintertime on all the measured sites varied from 3.6 to 4.2%.

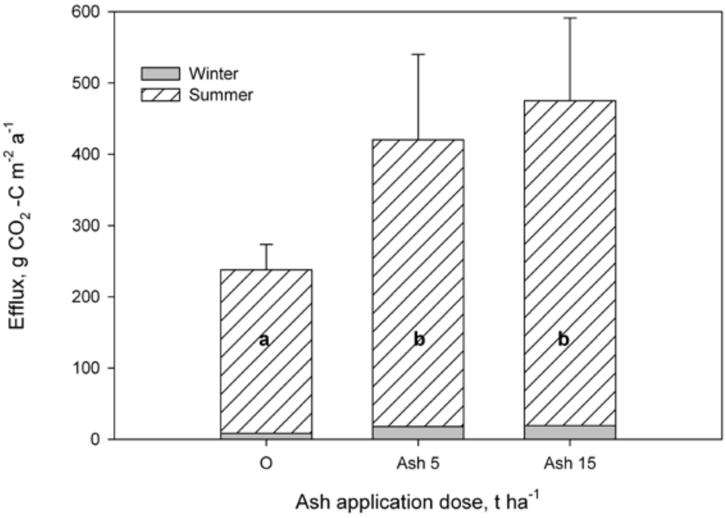

Figure 1. Annual soil CO_2 emission (with standard deviation) for the time period May 2009-April 2010. Differences between the treatments marked with same letters are not statistically significant (Bonferroni test $p>0.05$).

Stand growth and carbon bound in stand biomass

The ash treatments increased considerably the growth of tree stand and the effect became stronger with time (Fig. 2). Compared to the growth level at the time of fertilization the ash application rate of 5 t ha^{-1} increased the annual volume growth almost 3-fold and application of 15 t ha^{-1} roughly 7-fold in 13 years. On the control plot the growth of trees remained unchanged or even decreased. At the time of CO_2 measurements the volume growth was 2, 11 and 13 m^3 ha^{-1} in control, ash 5 t ha^{-1} and ash 15 t ha^{-1} treatments, respectively.

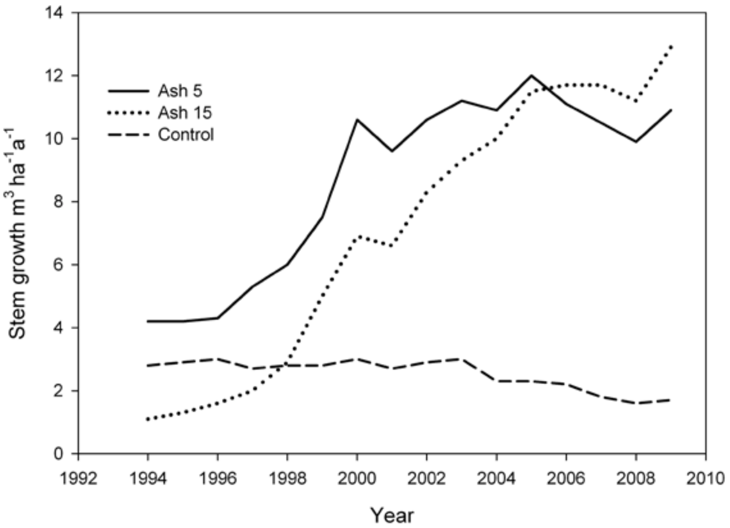

Figure 2. Annual volume growth of the Scots pine in 1994 - 2009. Ash applications in early summer 1997.

During the CO_2 measurement period, the trees bound carbon in their biomass on the control plot 34 g m^{-2} of C (Fig. 3). The ash applications increased considerably the amount of carbon in the biomass: in the bound C amount was 371 g m^{-2} and 417 g m^{-2} for the ash 5 t ha^{-1} and ash 15 t ha^{-1} treatments, respectively. Annual difference between peat C emission and C bound by trees on the ash plots varied 43 – 58 g m^{-2}, while on control plot it was 204 g m^{-2}.

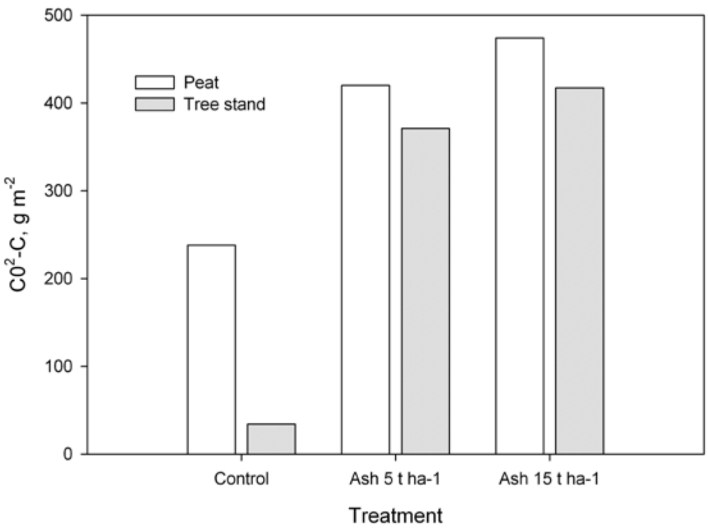

Figure 3. Annual C emission from peat substrate and C accumulation of growing stock (above and below ground mass including needles and roots > 1 cm in diameter) by ash treatments 13 years from ash application.

DISCUSSION

We measured heterotrophic soil respiration in our site using plots trenched to depth of 30 cm to suppress the root activity. Most of our measurements were done one growing seasons following trenching. Therefore we assumed that the influence from fine root residues to soil respiration were negligible.

After 13 years of application, wood ash almost doubled peat heterotrophic CO_2-C emission. This is considerably more than presented in earlier studies carried out on peat soils. Maljanen *et al*. (2006) reported an increase of approximately 30% in CO_2 emissions 15 years after the ash application.

It is probable the increased emissions due to ash application continue for a long time even though long term studies have not been made. It can be assumed that the effect of ash is quite long lasting, since soil pH and the amount of nutrients has stayed in higher levels for decades after the ash fertilization (e.g. Moilanen *et al*., 2002). Furthermore, in a study by Maljanen *et al*. (2006) it was showed that CO_2 emissions from the site were sill 24 % higher after 50 years since ash application than than in unfertilized control.

The growing stand biomass on the control plot had bound only about 14 % of the C released from the peat. The increased biomass production on ash-plots remarkably reduced the total emission of carbon from the site. Tree stand on ash plots bound an amount of C which was 11–12-fold higher than in the control. In earlier studies, the effect of wood ash application on tree growth has noted to be increasing for 2 – 3 decades from application and has continued even 50 years or longer (e.g. Moilanen *et al*., 2002, 2005). Therefore, our results suggest that the study site will turn from C source to C sink within the next 10 -15 years. However, additional research in different stages of stand development is needed for clarifying the role of tree stand in the C cycle in drained and ash-fertilized peatland forests.

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