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Can intense forest fertilization be considered a sustainable management practice in the context of greenhouse gas exchange between soils and the atmosphere?

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The demand for forest biomass is increasing and there is large potential for increasing biomass production of northern forest ecosystems by various management strategies involving N fertilization. Increased biomass production also leads to more atmospheric carbon sequestration that potentially can mitigate climate change. N fertilization has been shown to increase biomass production and to decrease soil respiration rates. However, the potential increase in N2O emissions following N addition may counteract the sustainability of such management practices in terms of its impact on the sink/source relationship of greenhouse gases.
Here we evaluate the effect of various N addition intensities on the soil-atmosphere exchange of CO_2 and N2O in a long-term field experiment in a boreal Scots pine (Pinus sylvestris) forest stand. The stand was planted in 1953 and the experiment was established in 1974 with annual N addition at four levels (N0, N1, N2, and N3 receiving 0, 35, 70, and 110 kg N ha-1 year-1, respectively) organized in a randomized block design (n=3) in plots of 30x30m. The high (N3) and intermediate (N2) N addition levels were terminated in 1990 and 2006, respectively, and offered an opportunity to investigate recovery of greenhouse gas exchange following high N loading. Soil-atmosphere exchange of GHGs were estimated weekly during 2010-2011 based on static chamber measurements during the snow free period and snow concentration gradients during winter.
In the ongoing treatment (N1) the annual N2O emissions were 25 mg N2O m-2 yr-1, as compared to 6 mg N2O m-2 yr-1 in the control plots, representing a ca 4-fold significant increase due to N-addition. The N2O-N loss from the treatment corresponded to ca 0.5% of the annually added N (35 kg N ha-1). In the N2 treatment (terminated in 2006) annual N2O emissions were 15 mg N2O m-2 yr-1, while in the N3 treatment N2O emissions were the same as in the control plots with no N-additions. Thus the system has capacity to recover with respect to N2O emissions on decadal time scales after termination of high long-term N loading.
Soil CO_2 emissions were reduced in all treatments as compared to the control plots. Even if N addition markedly increased N2O emissions these were quantitatively small compared to the reduction in soil CO_2 emissions when compared as CO_2-equivalents. Moreover, the N-additions in N1 led to a ca 30% increase in C sequestration into biomass, further reducing the negative effect of increased N2O emissions in the context of the total GHG balance of the forest stand. We will also present data exploring the long-term GHG dynamics and C sequestration in the forest stand following N additions using the COUP-model.