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## Continuous multi-plot measurements of CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O and H<sub>2</sub>O in a managed boreal forest – The importance of accounting for all greenhouse gases

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In order to assess the effects of different management practices on the exchange of greenhouse gases (GHG), it is desirable to perform repeated and parallel measurements on both experimental and control plots. Here we demonstrate how a system combining eddy covariance and gradient techniques can be used to perform this assessment in a managed forest ecosystem.

The net effects of clear-cutting and stump harvesting on GHG fluxes were studied at the ICOS site Norunda, Sweden. Micrometeorological measurements (i.e., flux-gradient measurements in 3 m tall towers) allowed for quantification of CO<sub>2</sub>, CH<sub>4</sub> and H<sub>2</sub>O fluxes (from May 2010) as well as N<sub>2</sub>O and H<sub>2</sub>O fluxes (from June 2011) at two stump harvested plots and two control plots. There was one wetter and one drier plot of each treatment. Air was continuously sampled at two heights in the towers and gas concentrations were analyzed for CH<sub>4</sub>, CO<sub>2</sub>, H<sub>2</sub>O (LGR DLT-100, Los Gatos Research) and N<sub>2</sub>O, H<sub>2</sub>O (QCL Mini Monitor, Aerodyne Research). Friction velocities and sensible heat fluxes were measured by sonic anemometers (Gill Windmaster, Gill Instruments Ltd). Automatic chamber measurements (CO<sub>2</sub>, CH<sub>4</sub>, H<sub>2</sub>O) were carried out in the adjacent forest stand and at the clear-cut during 2010.

Average CO<sub>2</sub> emissions for the first year ranged between 14.4–20.2 ton CO<sub>2</sub> ha<sup>-1</sup> yr<sup>-1</sup>. The clear-cut became waterlogged after harvest and a comparison of flux-gradient data and chamber data (from the adjacent forest stand) indicated a switch from a weak CH<sub>4</sub> sink to a significant source at all plots. The CH<sub>4</sub> emissions ranged between 0.8–4.5 ton CO<sub>2</sub>-eq. ha<sup>-1</sup> yr<sup>-1</sup>. N<sub>2</sub>O emissions ranged between 0.4–2.6 ton CO<sub>2</sub>-eq. ha<sup>-1</sup> yr<sup>-1</sup>. Enhanced N<sub>2</sub>O emission on the drier stump harvested plot was the only clear treatment effect on GHG fluxes that was observed. Mean CH<sub>4</sub> and N<sub>2</sub>O emissions for the first year of measurements amounted up to 29% and 20% of the mean annual CO<sub>2</sub> emissions, respectively. This highlights the importance of including all GHG when assessing the climate impacts of different forest management options.

Our results show that continuous multi-plot measurements of the main GHGs are possible also at sites where GHG fluxes are low, at a reasonable cost and with reduced plot inter-comparison uncertainties.