Geophysical Research Abstracts
Vol. 20, EGU2018-15839, 2018
EGU General Assembly 2018

The greenhouse gas balance of a managed boreal landscape measured from a tall tower in northern Sweden

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Climate change is mainly driven by the rising greenhouse gas (GHG) concentrations in the atmosphere, with carbon dioxide (CO_2) and methane (CH_4) accounting for $\sim$80% of the total radiative forcing from well-mixed GHGs. Boreal forested landscapes exchange large amounts of CO_2 with the atmosphere via photosynthesis and decomposition and are considered important carbon sinks for mitigating climate change. Emissions of CH_4 are generated from the boreal mires and the living biomass, plant litter, and woody debris under anaerobic conditions in the forests; meanwhile, CH_4 is consumed by the well-aerated soils. Up to date, technical challenges and large uncertainties still exist in quantifying GHG budgets at a landscape scale. Additionally, forest management practices play a significant role in modifying the GHG balances. It is currently under debate whether the managed boreal landscape is a sink or source of GHGs.

In this study, we provide the first baseline measurements of CO_2 and CH_4 fluxes over a managed boreal landscape ($\sim$68 km^2) in northern Sweden, using a tall eddy covariance (EC) flux tower. Two EC systems are mounted at 70 and 85 m above ground to measure the turbulent fluxes of CO_2 and CH_4. Profile measurements of CO_2 concentrations and air temperatures are made at 15 levels, ranging from 4.2 to 150 m. Concentrations of CH_4 are measured at 35, 85, and 150 m, respectively. During the two growing seasons (March 15-October 15) in 2016 and 2017, the cumulative net ecosystem exchange of CO_2 was -270 and -181 g C m^{-2}, respectively. Over an annual basis from March 2016 to February 2017, the managed boreal landscape was a net CO_2 sink of -132 g C m^{-2} yr^{-1}. The clear-cut areas within the landscape were a net CO_2 source of $\sim$300 g C m^{-2} yr^{-1} and hence largely reduced the landscape carbon sink strength. We estimated that maximum of 36% spatial coverage of clearcuts can be allowed to ensure the landscape remain a net carbon sink. During the CH_4 measurement period from July 13 to September 30 in 2017, the mean CH_4 flux was a net emission of 3.1 nmol m^{-2} s^{-1}. As CH_4 has a 28 times stronger global warming potential than CO_2 over a 100-year time horizon (IPCC AR5), the overall GHG budget of the boreal landscape was approximately -0.7 t CO_2-eq ha^{-1} yr^{-1} and indicated the investigated boreal forest landscape to be a sink for radiative forcing in 2017. These results clearly highlight that landscape scale measurements of the land-atmosphere GHG exchange are essential for an accurate estimate of the role of boreal forests for mitigating climate change.