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Energy and carbon dioxide fluxes in clear-cut and undisturbed boreal forests in Russia

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Boreal forests cover large areas in the northern hemisphere and have significant impacts on the climate system. Clear-cutting and other forest disturbances substantially change natural biogeochemical and biogeophysical cycles and can influence climate conditions at local to global scales. Such effects can be particularly strong in boreal forest areas of European Russia, mainly due to intensified logging activity over recent decades. How these forest disturbances will influence the ecosystem-atmosphere exchange has not yet been sufficiently investigated and requires aggregated experimental and modeling studies.
Here we report novel results of eddy covariance flux measurements at two forest sites: an undisturbed mature spruce forest and a recently clear-cut area. The flux measurements in the clear-cut area were provided during the first growing season following harvest. Both selected forest sites are situated in the same area within a close distance from each other that provides similar weather and moistening conditions. We detected a strong influence of the clear-cut on energy balance components and CO_2 fluxes between forest ecosystems and the atmosphere. The latent (LE) and sensible (H) heat fluxes at the undisturbed forest site were predominantly larger of clear-cut fluxes over the entire measuring period. The Bowen ratio (β) for both sites varied significantly over time. In spring, the H values were approximately equal to the LE values at both sites, whereas the LE was greater than H values during summer ($\beta \approx 0.2$ for clear-cut and $\beta \approx 0.4$ for spruce forest). When averaged for the entire measuring period, the mean β values of the two sites were similar ($\beta \approx 0.5$ for both sites). By CO_2 flux analysis, we found that the clear-cut site was a permanent source of CO_2 for the atmosphere (net ecosystem exchange (NEE) 3.3 $\pm$ 1.3 gC m-2 d-1), while the NEE of the mature undisturbed forest was close to zero (NEE 0.1 $\pm$ 1.9 gC m-2 d-1). We detected substantial differences in gross primary production (GPP) between the sites (7.0 $\pm$ 4.1 gC m-2 d-1 and 4.1 $\pm$ 3.0 gC m-2 d-1 for the mature forest and clear-cut site respectively), whereas ecosystem respiration (RE) did not differ significantly (7.1 $\pm$ 3.6 gC m-2 d-1 in the mature forest and 7.4 $\pm$ 3.4 gC m-2 d-1 in the clear-cut). We also detected increased temperature sensitivity of RE and decreased light use efficiency of GPP under the low PAR values in the mature forest. The clear-cut site of the southern taiga is distinguished by relatively high carbon dioxide fluxes over boreal clear-cut sites where carbon dioxide fluxes have been reported.
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