Energy and CO_2 fluxes in a recently clear-cut spruce forest in European Russia.

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Abstract

Ecosystem carbon dioxide, energy, and water fluxes were measured using eddy covariance and portable chambers in a fresh clear-cut surrounded by a mixed spruce-birch-aspen forest in the boreal zone of European Russia. Measurements started in April 2016 following timber harvest and continued for height months. Results showed that the clear-cut was a permanent source of CO2 to the atmosphere. Total Ecosystem Respiration (TER) and Gross Primary Production (GPP) were about 7.4±3.4 gC·m-2 and 4.1±3.0 gC·m-2 per day, respectively. TER derived by eddy covariance technique showed a reasonable accordance with RE obtained by chamber methods. During the mid-spring the mean daily latent (LE) and sensible (H) heat fluxes were very similar and the Bowen ratio (β=H/LE) averaged about 1.0. During the late spring and summer months the net ecosystem exchange of CO2 (NEE) remained slightly positive following onset of vegetation growth, while β was changing in the range from 0.3 to 0.5. There was strong diurnal variability in NEE, LE and H over the measurement period that was governed by solar radiation and temperature as well as the leaf area index (LAI) of regrown vegetation.

Study site

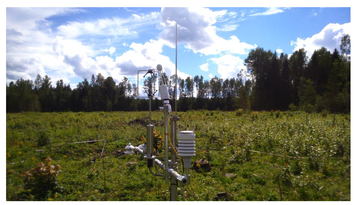

Fig. 1 Geographical location and photo of the clear-cut area

The clear-cut area is situated in the area of sustainable environmental management of the Central Forest State Natural Biosphere Reserve in the Tver region of Russia (56°260N, 33°030E) far from any anthropogenic sources of air or water pollution. The topography is almost flat with a gentle slope that does not exceed one degree. The mixed spruce-birch-aspen forest was clear felled in winter–early spring 2016 and cover around 4.5 ha. Active regeneration of herbaceous species, low-growing shrubs and juvenile trees within the clear-cut began on the second part of May. Vegetation one-sided leaf area index (LAI) reached 2.5 $m^2 \cdot m^{-2}$ and a maximum height of 70–90 cm in late August. The amount of organic carbon in the upper 10 cm soil layer within the clear-cut varied from 2.73 to 5.79%. The height of surrounding forest ranged between 18 and 22 m.

Methods

Meteorological and eddy covariance measurements

Equipment for meteorological and eddy covariance flux measurements (Tab. 1) was mounted at a height of 2.4 m on a 3m tall steel tripod (CM 106B, Campbell Sci. Inc., USA) installed in the northern part of the clear-cut taking into account dominating wind direction.

Turbulent energy and CO2 fluxes as well key meteorological parameters were collected at a 10 and 0.1 Hz rate, respectively. The fluxes were calculated at 30-min intervals using the EddyPro software (LI-COR Inc., USA).

U*-filtering, gap-filling and NEE partitioning into TER and GPP was performed by REddyProc online tool, which is based on procedures described by (Reichstein et al ., 2005).

The footprint was estimated using the (Kljun et al., 2004) model. During the entire measurement period the mean fetch length was about 26 m, which was significantly less than the distance between the measuring system and the nearest forest edge (circa 90 m in north direction).

Chamber Measurements

Closed (non-steady state) chamber measurements were used to quantify the spatial variability in CO_2 flux within the clear-cut. Additionally, they are able to verify the flux measurements provided by eddy covariance technique.

Estimated meteorological parameters	Instrument
Air temperature and humidity, wind speed and direction, precipitation rate	Automatic meteorological station WXT 520 (Vaisala Inc., Finland)
Net radiation, incoming and outgoing short-wave and long-wave radiation fluxes	Net radiometer NR01 (Hukseflux Thermal Sensors, The Netherlands)
Photosynthetically active radiation (PAR)	Quantum sensor LI-190R (LICOR Inc., USA)
Soil temperature and water content	Reflectometers CS655 (Campbell Sci. Inc., USA)
Soil heat flux	Heat flux sensors HFP01SC (Hukseflux Thermal Sensors, The Netherlands)
Gas concentrations (eddy covariance)	CO_2/H_2O gas analyzer LI-7500A (LI-COR Inc., USA)
Wind components, sonic temperature	3-D ultrasonic anemometer WindMaster Pro (Gill Instruments, UK).
Gas concentration (chambers)	CO_2 analyzer LI-840 (LI-COR Inc., USA)
Leaf area index (LAI)	AccuPARLP-80 (Decagon Devices Inc., USA)

Tab.1 Measured meteorological parameters and instruments

Results

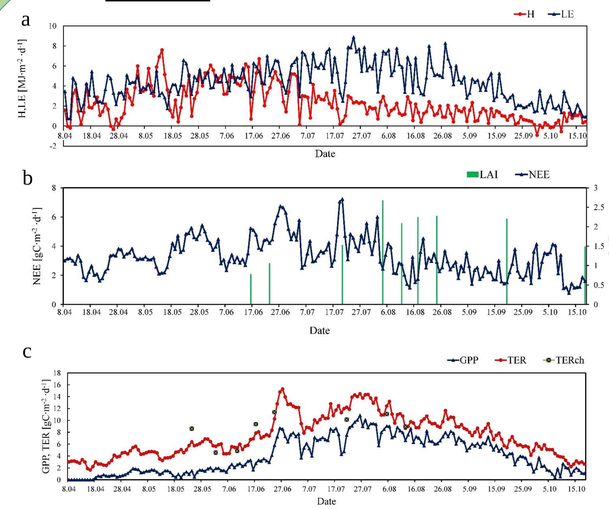

Fig.2 Temporal variability of daily (a) H, LE, (b) NEE of CO_2, and (c) GPP and TER measured using eddy covariance and chamber method (TERch)

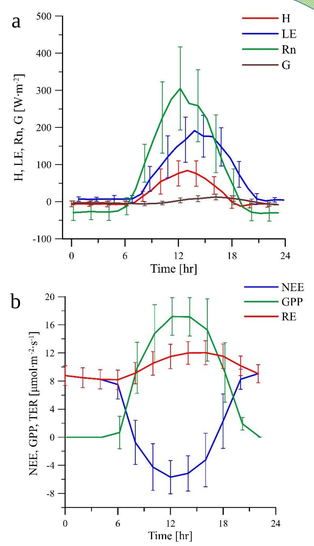

Fig.3 Diurnal variability in mean (a) Rn, H, LE and G, (b) as well as NEE of CO2, GPP and TER in August 2016 (with standard deviations).

The mean daily air temperature varied between -1.7 and 23.8 °C. A large amount of precipitation (459 mm) provided sufficient soil moisture conditions to prevent plant water stress during the entire measuring period (volumetric soil water content ranged between 0.35 and 0.48 $m^3 \cdot m^{-3}$). Incoming solar radiation was mainly influenced by cloud cover and varied between 1.1 and 26.6 MJ m2 per day. The net radiation ranged between -0.8 and 12.8 MJ m^{-2} per day.

The Bowen ratio varied around 1 in spring months and June. Since the July decreasing H and growing LE rates provided a lower β values down to 0.3-0.5 in the late summer. The maximal diurnal amplitude of energy fluxes was estimated in August.

Mean daily TER values exceeded mean daily GPP during the whole period of measurements. Hence the clear-cutting was a permanent source of CO_2 for the atmosphere. Mean CO2 emission rate was about 3.3±1.3 $gC \cdot m^{-2}$ per day. However the midday NEE flux in late summer was negative. TER values calculated from eddy covariance data shown a good agreement with chamber measurements.

Conclusions

- New clear-cut showed a rapid changes in energy (H, LE) and CO2 (NEE, GPP, TER) fluxes during the period of measurements that were governed mainly by atmospheric conditions and vegetation regrowth.
- The clear-cut was a source of CO_2 to the atmosphere during the entire period (NEE > 0 $gC \cdot m^{-2}$ per day), in spite of the dominating of GPP over TER in the midday time in late summer.
- Bowen ratio was around 1 during early spring, but declined to around 0.3-0.5 during summer when daily LE tended to exceed H.
- Our results agreed well with carbon dioxide and energy fluxes measured in clear-cuts in other geographical regions despite differences in meteorological conditions, vegetation, soil, and instrumentation.

References

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1. Acknowledgements

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