Geophysical Research Abstracts
Vol. 18, EGU2016-3241-2, 2016
EGU General Assembly 2016


# The effect of deforestation and land-use changes on $CO_2$ and $H_2O$ exchange between land surface and the atmosphere in the Upper Volga area in Russia

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The main goal of the study to describe the possible impact of deforestation (or/and afforestation) and land-use changes in the Upper Volga area in European Russia on regional fluxes of sensible heat, $H_2O$ and $CO_2$ between a land surface and the atmosphere as well as on regional climate conditions. This is experimental and modeling study that integrates intensive field campaigns to derive the spatial and temporal variability of $H_2O$ and $CO_2$ fluxes at the local ecosystem scale, analysis and interpretation of remote sensing data, development and application of local scale process-based 2D and 3D turbulent transfer models to quantify atmospheric fluxes, analysis of paleogeographical data to reconstruct vegetation dynamics in past epochs and its interaction with climatic conditions, application of mesoscale models to derive the possible influence of deforestation and land-use changes on regional climate under present and projected future climate conditions.
To describe the difference in the $H_2O$ and $CO_2$ exchange between anthropogenically changed (e.g. a clear-cut area) and undisturbed forest the eddy covariance measurements was applied. The spatial heterogeneity of soil respiration within the clear-cut area and surrounding forest the chamber method was used. In particular it was shown during the field measurements that the soil $CO_2$ emission from clear-cut plots is significantly exceed $CO_2$ emission rate from control plots within surrounding forest. For all plots it was shown a well manifested seasonal course of soil respiration and quite small amplitude of its diurnal variability. It was revealed a close dependence of soil $CO_2$ emission from temperature and moisture of the upper soil horizon. It was found that the plots with various damage degrees of the upper soil horizon, and non-damaged soil covered with a litter and felling remains are characterized by different respiration rates and different dependences on environmental factors.
To assess the influence of clear cuttings or windthrows on turbulent transfer of $CO_2$ between land surface and the atmosphere the numerical experiments using the developed set of two and three - dimensional hydrodynamic transfer models were carried out (Mukhartova et al. 2015, Levashova et al. 2015). Results of model calculations showed that a clear-cutting leads, on the one hand, to a strong increase of horizontal exchange rate within clear-cut area, and, on the other hand, to the strengthening of vertical exchange at the windward forest edge and its weakening - at its leeward parts (Mukhartova et al. 2015). Results of model calculations showed also an essential influence on vertical fluxes of relief heterogeneity.
To describe the modern dynamics of vegetation and land use for the area of Upper Volga in our study the MODIS data for period from 2001 to 2013 were used. The results showed that during the period a small decrease of the areas covered by coniferous forests (from 3.7 to 1.4%), an insignificant increase of the areas of broad-leaved forests (from 0.3 to 0.6%), and a strong increase of the areas of mixed forests (from 68.5 to 77.8%) were detected. If a decrease of the areas covered by coniferous forests can be explained by active spruce timber harvesting and slow forest renewal, the main reason for a significant growth of the mixed forest areas can be active processes of forest regeneration in the thrown farmlands, clear-cuts, windthrows and meadows. By the same factors can be explained an increase of the areas covered by bushes (from 0.2 to 0.9%). An increase in the areas of mires (from 1.4 to 2.2%) can be explained by deterioration of surface water drainage, by increase of peat accumulation rate as well as by uncontrolled logging of the swampy spruce stands.
In order to assess the influence of regional vegetation and land use changes on climatic system the mesoscale COSMO_CLM model was applied. For model projections the recent information about the main trends in vegetation and land-use changes at present (remote sensing) and in the past (paleo-reconstructions) were used. Several scenarios considering the different anthropogenic impacts were developed. The results of model calculations

showed that under present climate conditions the maximal influence of deforestation on climatic conditions during the warm season is predicted for years with more wet weather conditions, and minimal - for years with more dry and warm weather conditions. In particular, under present climate conditions an extremely strong deforestation (by 50%) can lead for more rainy years to temperatures increase in summer months by 0.2°C, and precipitation decrease - by about 12%. For more dry years the 50% deforestation doesn't lead to any essential changes in the summer temperatures and precipitation amount that actually is a quite unexpected result, and it is obviously demanded in additional check by calculations for more long time periods and larger areas, as well as, perhaps, using alternative mesoscale models.

This study is involved in the NEESPI program and it was supported by grant of the Russian Science Foundation (14-14-00956).