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Windthrow and fallow-forest successions impacts in soil carbon stocks and GHG fluxes spatial variability and dynamics in the Central Russia' reserve spruce ecosystems

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High spatial and temporal variability is mutual feature for most forest soils that is especially obvious in case of their carbon stocks and GHG fluxes. This phenomenon is generally well-known but not so often becomes the object of special precision investigation in detail and small scales so there are still serious gaps in its principal factors understanding due to their high bioclimatic, regional, landscape, tree species and temporal variability. Southern taiga is one of the most environmentally important world zonal forest ecosystems due to its still comparatively intensive carbon biogeochemical cycle and huge area in the northern Eurasia with strong anthropogenic impacts by Western & Central European and Southern & Eastern Asian regions.

Central Forest Biospheric Reserve (Tver region, 360 km to North-West from Moscow) is the principal southern-taiga reserve in the European territory of Russia. Since start of its research activity in 1939 the reserve became the regional center of mature spruce ecosystem structure and dynamics investigation. In 1970-1980-s there have been done complex investigations of windthrow soil patterns and fallow-forest successions. Since middle of 1990-s the ecosystem-level GHG fluxes have been observed by eddy covariance method. Since 2012 the detailed year-round monitoring is running in the southern-taiga zonal station of the regional system RusFluxNet with especial attention on the soil carbon stocks and GHG fluxes spatial variability and dynamics due to windthrow and fallow-forest successions (in frame of RF Governmental projects #11.G34.31.0079 and #14.120.14.4266).

Soil carbon dynamics is investigated in decades-hundred-year chronosequences of dominated parcels and different-size windthrow soil cover patterns, including direct investigation during last 33 years with detailed mapping, soil profile morphometrics and bulk density, morphogenetic and statistical analysis of mass data. Morphogenetic analysis of microrelief, soil profile and cover have been accompanied by researches of soil regimes (temperature, moisture, pH, oxidation-reduction potential, microbiological activity) and transformations of representative topsoil materials at the different stages of windthrow soil successions. Since 2012 soil CO_2 fluxes have been analyzed every ten days in situ by method of exposition chambers with infra red gas analyzer (Li-Cor 820). At the same periods soil gas fluxes have been sampled from the exposition chambers into vials with the following CH4 and N2O analysis by gas chromatograph.

The carried out researches have shown sharp increase of rates of typomorphic soil forming processes within windthrow hole and mound soil successions: (a) lateral input of organic matter in soils of fresh holes – up to 2-3 kg m-2y-1; (b) fulvic acid formation – up to 100-200 g m-2y-1 in soils of young holes and mounds; (c) Al-Fe-humus migration – up to 0.7-1.2 kg cm m-2y-1; (d) humus-accumulated and eluvial horizon development – up to 1-2 mm y-1. The conducted researches have shown high temporal and spatial variability of CO_2 fluxes due to soil cover and windthrow complex patterns, windthrow or fallow-forest succession stage and age, air and soil temperature (up to R = 0.64 for taiga, and R = 0.75 for fallow), soil moisture (up to R = -0.65/0.66 both for taiga and fallow) and some other characteristics of the studied objects. Soil CO_2 emission is essentially decreased with fallow-forest age. Maximum CO_2 fluxes have been observed between 12:00 and 16:00. Within fallow-forest succession the maximum CH4 emission has been fixed in first (grass) stage, and N2O fluxes increase due to temperature rise and moisture decreasing. Usually there is stronger effect on GHG fluxes by air temperature than soil one due to comparatively thin layer of soil organic and/or humus-accumulative subhorizons with maximum biological activity that usually determines the total rate of GHG principal soil fluxes. Unfavorable seasonal climatic conditions (dry season or low temperature) determine essential (in 1.5-2 times) decreasing not only in soil GHG fluxes but in level of their spatial variability, seasonal and daily dynamics too. These trends are most obvious in case of more open ecosystems at the first stages of the fallow-forest succession. Understanding the principal regularities of spatial and temporal changes in soil GHG fluxes help better modelling them in the process of spatial intra- and extrapolations, seasonal and interseasonal predictions, taking into attention basic and current principal factors limiting GHG fluxes.