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Carbon balance responses to water stress conditions in differently managed windthrow forest sites

Janusz Olejnik (1,2), Klaudia Ziemblińska (1), and Marek Urbaniak (1)

(1) Poznan University of Life Sciences, Meteorology Department, Poznan, Poland (janusz.olejnik@up.poznan.pl), (2) Global Change Research Centre, Matter and Energy Fluxes,Brno, Czech Republic

Carbon and water dynamics of disturbed forest sites differ significantly from the mature stand. Stand-replacing phenomena as windthrow do not only alter forests' ability to sequester carbon but also affects water vapor exchange with the atmosphere due to the great reduction of evapotranspiration. The choice of reforestation technique at these vulnerable post-windthrow sites turns out to be crucial regarding not only net CO_2 emissions changes in time but also the young plantation resistance to the water stress conditions. In this study we have compared results of already 6 years of continuous, real-time measurements at two windthrow forest sites in Trzebciny Forest District in northwest Poland. The main objective of this study was to determine how two completely different reforestation techniques in windthrow areas impact net ecosystem production (NEP) of this Scots pine forest ecosystem under similar meteorological and soil conditions. These two techniques were: conventional (Tlen I site- uprooted stumps pulled out and removed from the site followed by ploughing), and non-conventional (Tlen II site- all stumps left on the site to decompose with no ploughing). At both sites we measured carbon dioxide (CO_2) and water (H_2O) fluxes using the eddy covariance (EC) technique.
Our results indicate that both sites became significant carbon (C) sources after the windthrow (up to 575 56 g C m-2 y-1 in the first year, Tlen I). However, the Tlen I (conventional technique) lost over 30% less C than Tlen II during the 2015-2016 observation period. In the next two years (2017-2018) the decrease in net C emission was several times greater at Tlen I than at Tlen II. Moreover, the annual net ecosystem production (NEP) at conventionally reforested windthrow site reached C neutrality (NEP = 0) six years after windthrow, while the non-conventionally managed area was still a significant C source. So far then, the currently widely applied conventional reforestation technique in wind-disturbed Polish forest appeared to be more effective in decreasing C losses than a technique that leaves stumps to decompose and avoids ploughing. During the study period there were two relatively wet years (2016 and 2017) which allowed both Scots pine plantations to grow and develop very well. Although, the occurrence of summer drought in 2015 affected the non-conventionally reforested treatment, while at the site which had been ploughed, there was no sign of water stress. It comes from the fact that furrows, where organic matter lays upside-down on the previous soil cover, served well as a retention agent, supplying young trees with water at the times of its shortage. Similar effect was visible also in spring 2018. The results from both study areas were also compared with CO_2 and H_2O fluxes from the mature pine stand (Tuczno site) - the closest analogue to the pre-storm stands from the Tlen I and Tlen II sites.
Presented studied gives an insight into the carbon and water dynamics at differently managed wind-disturbed forest sites, stressing out the differences in coping with water stress.