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Regional variability of environmental effects of energy crop rotations

Anne-Katrin Prescher (1), Christiane Peter (1), Xenia Specka (2), Matthias Willms (1), and Michael Glemnitz (3)

(1) Institute of Landscape Systems Analysis, Leibniz Centre for Agricultural Landscape Research (ZALF), Eberswalder Straße 84, 15374 Müncheberg, Germany (prescher@zalf.de), (2) Institute of Landscape Biogeochemistry, Leibniz Centre for Agricultural Landscape Research (ZALF), Eberswalder Straße 84, 15374 Müncheberg, Germany, (3) Institute of Land Use Systems, Leibniz Centre for Agricultural Landscape Research (ZALF), Eberswalder Straße 84, 15374 Müncheberg, Germany

The use of energy crops for bioenergy production is increasingly promoted by different frameworks and policies (ECCP, UNFCCC). Energy cropping decreases greenhouse gas emissions by replacing the use of fossil fuel. However, despite this, growing in monocultures energy crop rotations has low environmental benefit. It is broadly accepted consensus that sustainable energy cropping is only realizable by crop rotations which include several energy crop species. Four crop rotations consisting of species mixtures of C_3, C_4 and leguminous plants and their crop positions were tested to identify the environmental effect of energy cropping systems. The experimental design included four replicates per crop rotation each covering four cultivation years. The study took place at five sites across Germany covering a considerable range of soil types (loamy sand to silt loam), temperatures (7.5 ˚C – 10.0 ˚C) and precipitation (559 mm – 807 mm) which allow a regional comparison of crop rotation performance. Four indicators were used to characterize the environmental conditions: (1) greenhouse gas (GHG) emissions from the management actions; (2) change in humus carbon (C_{hum}); (3) groundwater recharge (R_{GW}) and (4) nitrogen dynamics. The indicators were derived by balance, by an empirical model and by a dynamic model, respectively, all based and calibrated on measured values. The results show that the crop rotation impact on environmental indicators varied between plant species mixtures and the crop positions, between sites and climate. Crop rotations with 100 % energy crops (including C_4 plants) had negative influence on C_{hum}, GHG emissions per area and R_{GW} in comparison to the rotation of 50 % energy crops and 50 % cash crops, which were mainly due to the remaining straw on the field. However, the biogas yield of the latter rotation was smaller, thus GHG emissions per product were higher, pointing out the importance to distinguish between GHG emissions per product and per area. The perennial legume rotation was identified as the most beneficial and eco-friendly energy crop rotation by showing an increase in C_{hum}, lower GHG emissions per product and area and positive effects on nitrogen dynamics. However, the absolute magnitude of changes and effects differs between the sites indicating an influence of soil type and local climate on the final performance of the energy crop rotation. Generally, the results showed that the positive effect of a certain crop rotation on particular environmental indicators can have a less beneficial effect on another indicator, making an overall evaluation of the energy crop rotation complicated. The weighing of different environmental indicators finally depends on the environmental priorities, political targets and describes a further challenge.