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Soil carbon sequestration under Miscanthus x giganteus – A large scale survey

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The use of biomass for energy production is considered to be a promising way to reduce net carbon emissions and mitigate climate change. However the benefits of bioenergy have been open to debate. Particularly because land-use change to bioenergy crops can result in carbon emissions from soil and vegetation in amounts that could take decades of bioenergy crop production to compensate for. Perennial crops (e.g. Miscanthus or switchgrass) offer a possible solution to this problem as measurements on experimental Miscanthus plots have shown carbon sequestration potential. It can, however, be expected that sequestration potentials in commercial use might substantially differ from those measured in experimental plots due to different farming practices and a wider range of soils and climate conditions.

For this study, commercial Miscanthus plantations on 16 farms in south east Ireland have been examined. Soil cores have been taken at 10 cm steps down to 30 cm depth. Soil organic carbon (SOC) has been measured on the Miscanthus fields as well as on adjacent control sites representing the former land-use (grassland and tillage). The amount of Miscanthus-derived carbon was determined using the 13C natural abundance method. Additionally soil bulk density, pH and particle size distribution were analysed.

On former tillage fields the analysis shows an average increase in total SOC stocks three years after Miscanthus planting (59.9 ±20.5 to 64.7 ±13.7 Mg C ha-1). Former grasslands show minor differences in carbon stocks (80.3 ±17.4 to 80.8 ±17.0 Mg C ha-1) the same time. Stable isotope measurements show that 3.0 ±2.3 % (1.9 Mg C ha-1) and 2.4 ±2.1 % (2.0 Mg C ha-1) of the organic carbon under former tilled and former grassland, respectively, were Miscanthus-derived. Linear mixed-effects models show that differences in overall as well as the Miscanthus-derived carbon stocks between the former land-uses and within the tillage treatment are significant.

Within the soil profile the total SOC in grassland control site shows a negative gradient. Three years after the introduction of Miscanthus the top 10 cm show a decline in total SOC, while from 10 to 30 cm the total SOC increases. Under the tillage control no gradient was observed, and on average the highest SOC stocks could be found in 10 to 20 cm depth. The introduction of Miscanthus did not change the pattern. On both former land-uses, Miscanthus-derived carbon was highest in the top 10 cm and lowest from 20 to 30 cm.

Mixed-effects models were used to link the total SOC concentrations and Miscanthus-derived carbon to the land-use parameters as well as to soil properties. It was shown that pH and clay content have a significant influence on the total SOC. The direction and magnitude of the influence, however, depended on the land-use parameters (former tillage vs. grassland, Miscanthus vs. Control) and sample depth, indicating underlying mechanisms in soil carbon dynamics. Additionally, for the Miscanthus-derived carbon, the remaining carbon concentrations had significant influence.

Altogether, high variations in soil carbon sequestration can be seen on commercial farms, indicating the necessity for detailed monitoring of carbon dynamics in bioenergy crops in order to verify greenhouse gas mitigation goals.