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Soil organic carbon stocks and fluxes due to land use conversions at the European scale

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European soils store around 73 to 79 billion tonnes of carbon, which is about 50 times the total CO_2-equivalent emissions of the 27 Member States of the European Union in 2009 (4.6 billion tones; EEA, 2010). More than twice as much carbon is held in soils as compared to the storage in vegetation or the atmosphere. Soil organic carbon (SOC) stocks are dynamic and changes in land use, land management and climate may result in instant losses, whereas gains accumulate more slowly over several decades. The soil organic carbon cycle is based on continually supplying carbon in the form of organic matter as a food source for microorganisms, the loss of some carbon as carbon dioxide, and the assimilation of stable carbon in the soil. The organic carbon stocks and fluxes to and from the soil across the EU were quantified for agriculture, forestry and peatlands under different land use change and management scenarios taking into account climate change and using a coupled regional balance and multi-compartment soil organic matter model (Roth-C).
Abolishing permanent grassland restrictions would have a negative effect on SOC stocks, which at the EU level can be quantified in a loss 30% higher than in the case of maintaining the current permanent grassland restrictions. Promoting the afforestation of 10% and 25% former set-aside land in the EU-15 would reduce the loss of SOC stock by 2030 by 19% and 65% respectively compared to conversions to arable land. An increase of the current afforestation rates by 2% would result in a 10% increase in carbon stock levels by 2030. The combined effect of the land use conversions to and from agricultural land use demonstrate an EU-27 average -9.7 tonnes/ha SOC stock loss for the worst option and a +5.0 tonnes/ha SOC stock gain for C-Rich option. Larger variations between Member States than between scenario options stem from regional differences in bio-geography, soil types and climatic regimes.
The amount of stable or humified organic carbon (HOC) assimilated depends on the yields, as these directly relate to potential residue production, and on the prevailing climate with cold temperatures and dry moisture regimes being less favourable. Incorporating all crop residues into the soil results in HOC fluxes that range from 1.36 tonnes HOC/ha for oilseed and 1.14 tonnes HOC/ha for cereal to 0.54 tonnes/ha for sugar beet. The HOC fluxes drop to 0.69, 0.58 and 0.05 tonnes HOC/ha respectively when all residues are removed, e.g. for bio-energy purposes. Taking into account the projected areas for cereals (65 Mha), oilseed (10 Mha) and sugarbeet (2 Mha) in 2030, shows that residue management of cereals has a much larger impact on carbon fluxes to the agricultural soil than oilseed and sugar beet. The removal of all crop residues result in a lowering of soil organic carbon stocks, a reduction of humified organic carbon fluxes into the soil and an increase of carbon dioxide concentrations in the atmosphere. A significant minimum percentage of crop residues should be retained in the soils.
Land management, land use changes and climate change have a significant influence on soil organic carbon stocks and fluxes across the EU-27. Determining the soil sequestration potential necessitates soil monitoring to provide evidence on the state of, and change, in agricultural soils, allowing to evaluate its effectiveness.