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Land management impact on soil organic carbon stocks – what do we really know?

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Abstract

Agricultural management and land use deplete soil organic carbon stocks with global impact on the soil carbon cycle. However, there are several management options in agriculture that aim at recovering the lost carbon and aim to sequester additional carbon. We reviewed several of these options performing quantitative meta-analysis in order to compile existing knowledge on their impact on soil organic carbon stock. Land use change from grassland to croplands had the strongest impact on total soil carbon stocks with 30 to 40% less carbon in tropical and temperate croplands as compared to grassland. Our result revealed that measures that increase the carbon input to the soil are the most effective to enhance soil organic carbon stocks. Regular growing of cover crops during winter season and subsequent use a green manure could increase soil carbon stocks by 300 kg ha^{-1} a^{-1}. In contrast, reduced or no-tillage did not significantly increase soil carbon stocks in temperate soils but only redistributed carbon in the soil profile. Moreover, no-tillage increased nitrous oxide emissions which strongly affected the greenhouse gas balance of no-tillage fields as compared to conventional tilled fields. Agricultural measures to enhance soil organic carbon should aim at synergies with other soil functions.

Keywords: land management, land use change, no tillage, cover crops, organic fertilisation

Introduction, scope and main objectives

With the four per mille initiative of the French Ministry of Agriculture launched at the COP21 in Paris 2016, new attention has been paid to the role of soil organic carbon in the global carbon cycle. Soil carbon sequestration may be an option to mitigate climate change but in agriculture soil organic carbon may be also a key to increase and sustain soil fertility and resilience of soils against climate change and climate extremes. Agriculture, thus, obtained the chance to switch from a major emittent of greenhouse gases to providing a possible solution for increasing atmospheric carbon dioxide concentrations through soil carbon sequestration. However, there are many unsettled expectation how adapted farming practice can enhance soil carbon. In order to substantially support the global aims of reduced greenhouse gas emissions via soil carbon sequestration enhanced quantitative knowledge I required how different land management option impact on soil organic carbon stocks. Thus, the aim of our research during the last 10 years was to compile this knowledge in several quantitative meta-analysis.

Methodology

We compiled data on soil organic carbon stocks after a certain land-management treatment and reference soil organic stocks from more than 1100 sites covering the globe with almost all climate regions. The following management options were assessed in detail:

1.) Land use change (mainly cropland – grassland and forest conversions)
2.) Cover crops
3.) Reduced and no-tillage
4.) Bioenergy production with perennial bioenergy crops.

Drivers that explain the various effects of land management on soil carbon at the different sites were compiled and statistical analysis was used to relate them to the land use and management effects.

Results

Results of or analysis are presented in several published papers. Land use change effects in the tropical and temperate zone are strong with highest soil carbon losses if native tropical forest is converted to cropland (Don et al. 2011). In the temperate zone soil organic carbon reacts much sower upon land use changes. Thus, it may take more than 100 year after land use change until a new steady state is reached (Poeplau et al. 2012). Cover crops increase the carbon input to the soil without compromising external biomass resources. With around 300 kg ha^{-1} a^{-1} cover crops are a very effective measure to increase soil carbon on croplands (Poeplau and Don 2015). The effects of reduced or no-tillage on soil carbon stocks are less clear that often discussed. We did not detect any significant soil carbon sequestration rate with reduced or no tillage in temperate soils. Even the oldest field trials revealed inconsistent results. However, increased nitrous oxide emissions due to reduced tillage may turn greenhouse gas balance of no-tillage into negative. Opposing to reduced tillage we also assessed the impact of deep tillage down to 100 cm and it long term effect on total soil carbon stocks. Surprisingly we found more than 40% higher soil carbon stocks several decades after the deep ploughing event (Alcantara et al. 2016).

We also explored new management techniques such as plantations of Miscanthus or short rotation coppice for bioenergy production. Such perennial crops partly also increase soil carbon stocks (Poeplau et al. 2014, Don et al. 2012, Walter et al. 2015).

Discussion

Soil organic carbon management is challenging with only selected methods being promising options to enhance soil organic carbon stock. These options should be also applied and evaluated site specifically. Not all management option can be applied to all soil types in all climate region thus requiring increased knowledge transfer to the management decision makers, the farmers.

Conclusions

Soil carbon sequestration should be one out of several measures to combat climate change. However, in order to implement agricultural soil carbon management, our abilities need to be increased to better site specifically predict the effects of different land use management options. With our extensive meta-analysis on different land use and management options with contributed to compile scattered knowledge into a more comprehensive picture.

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