Geophysical Research Abstracts
Vol. 20, EGU2018-9695-2, 2018
EGU General Assembly 2018

Are stability and turnover of soil organic matter driven by carbon saturation? A long-term bare fallow experiment

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Knowledge about soil organic carbon (SOC) turnover is of immense importance for assessing SOC storage and CO_2 emissions from the soil. Yet, spatial patterns of SOC turnover and their controlling factors are still uncertain. It is well known that clay and fine silt particles protect SOC through mineral associations but the proportion of these particles is limited. Once the amount of SOC in the soil approaches this maximum protection capacity, little additional SOC may be effectively protected by mineral associations, which is termed C saturation. Following this concept, we hypothesize that SOC is stored less stable and turns over faster at sites with high SOC contents but low protection capacity, i.e. at sites which are close to C saturation.

To investigate this hypothesis, we monitored spatial patterns of SOC losses from a former arable field site, which was eleven years under continuous bare fallow management. Long-term bare fallow experiments offer a unique opportunity to study the turnover of SOC and its regulating factors as all changes of SOC contents are directly linked to decomposition without being blurred by recent input of biomass. We calculated the protection capacity from the proportion of minerals < 20 μm. The degree of C saturation was calculated from the difference between the protection capacity and the actual C content of this particle size fraction (< 20 μm).

In the first year of bare fallow, the soil contained on average 12.1 g SOC kg-1 and revealed large variations in the degree of C saturation (41 - 78 %). The soil lost 0.6 g SOC kg-1, 1.7 g SOC kg-1, and 2.1 g SOC kg-1 after three, seven, and eleven years of bare fallow, respectively. The SOC losses after eleven years were spatially variable and varied between 1 % and 46 % relative to the initial SOC content. In support of our hypothesis, the degree of C saturation explained 82 % of SOC loss variability: largest SOC losses occurred at sites, which were close to C saturation. We conclude that the degree of C saturation is a suitable determinant for the stability and turnover time of SOC.