Geophysical Research Abstracts
Vol. 19, EGU2017-11321-1, 2017
EGU General Assembly 2017

Subsoil carbon accumulation on an arable Mollisol is retention dominated, in contrast to input driven carbon dynamics in topsoil

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The majority of the world's soil organic carbon (OC) stock is stored below 30 cm in depth, yet sampling for soil OC assessment rarely goes below 30 cm. Recent studies suggest that subsoil OC is distinct from topsoil OC in quantity and quality: subsoil OC concentrations are typically much lower and turnover times are much longer, but the mechanisms involved in retention and input of OC to the subsoil are not well understood. Improving our understanding of subsoil OC is essential for balancing the global carbon budget and confronting the challenge of global climate change. This study was undertaken to assess the relationship between OC stock and potential drivers of OC dynamics, including both soil properties and environmental covariates, in topsoil (0 to 30 cm) versus subsoil (30 to 75 cm). The performance of commonly used depth functions in predicting OC stock from 0 to 75 cm was also assessed. Depth functions are a useful tool for extrapolating OC stock below the depth of sampling, but may poorly model "hot spots" of OC accumulation, and be inadequate for modelling the distinct dynamics of topsoil and subsoil OC when applied with a single functional form. We collected two hundred soil cores on an arable Mollisol, sectioned into five depth increments (0-10, 10-20, 20-30, 30-50, and 50-75 cm), and performed the following analyses on each depth increment: concentration of OC, inorganic C, permanganate oxidizable carbon (POXC), and total N, as well as texture, pH, and bulk density; a digital elevation model was used to calculate elevation, slope, curvature, and soil topographic wetness index. We found that topsoil OC stocks were significantly correlated ($p < 0.05$) with terrain variables, texture, and pH, while subsoil OC stock was only significantly correlated with topsoil OC stock and soil pH. Total OC stock was highly spatially variable, and the relationship between surface soil properties, terrain variables, and subsoil OC stock was spatially variable as well. Hot spots of subsoil OC accumulation were correlated with higher pH (> 7.0), flat topography, a high OC to total N ratio, and a high ratio of POXC to OC. These findings suggest that at this site, topsoil OC stock is input driven, while OC accumulation in the subsoil is retention dominated. Accordingly, a new depth function is proposed that uses a linear relationship to model OC stock in topsoil and a power function to model OC stock in the subsoil. The combined depth function performed better than did negative exponential, power, and linear functions alone.