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Assessing the potential of stable carbon isotopes to better constrain the residence time of soil organic carbon using a depth-explicit modelling approach

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The residence time of soil organic carbon (SOC) varies considerably between different ecosystems and is difficult to measure using only field experiments. Therefore, models are often used to assess the residence time of SOC, but the range of optimal model parameters is often poorly constrained. This has important consequences for the reliability with which SOC dynamics are simulated by earth system models, leading to large uncertainties about the contribution of SOC to atmospheric CO_2 concentrations.

In order to improve the reliability of simulated SOC dynamics, and hence to assess more accurately the residence time of organic carbon (OC) in soils, we constructed a depth-explicit model that simultaneously simulates SOC dynamics and kinetic fractionation of stable carbon isotopes (δ13C). Using stable carbon isotopes as an additional constraint considerably increases our ability to interpret the observed SOC dynamics. For example, it allowed us to accurately assess the fraction of SOC lost after a forest ecosystem (C3 vegetation) was converted to cropland (corn – C4 vegetation). Through the evaluation the modelled depth profiles of δ13C against measured data, we are able to reduce the number of possible model parameters which result in an optimal simulation of SOC depth profiles. Therefore, the reliability of the simulated residence time of SOC increases significantly.

We used our model to simulate the residence time of SOC at colluvial landscape positions in a small sub-tropical catchment in southern Brazil. Comparison with colluvial landscape positions in temperate ecosystems shows that the residence time of SOC is much shorter in our sub-tropical ecosystems. In addition, this approach allows us to assess the fate of organic carbon from different sources (e.g. locally produced versus carbon deposited together with sediments), which significantly increases our understanding of SOC dynamics in these environments.