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Soil organic matter stability in agricultural land: New insights using δ15N, δ13C and C:N ratio

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Soil organic matter (SOM) contains three times more carbon than in the atmosphere or terrestrial vegetation. This major pool of organic carbon is sensitive to climate change, but the mechanisms for carbon stabilization in soils are still not well understood and the ultimate potential for carbon stabilization is unknown. For predicting SOM dynamics, it is necessary to gain information on the turnover rates or stability of different soil organic carbon pools. The common method to determine stability and age of SOM is the 14C radio carbon technique, which is very expensive and therefore limited in use. Conen et al. (2008) developed a model to estimate the SOM stability based on the isotopic discrimination of 15N natural abundance by soil micro-organisms, and the decreasing C:N ratio during organic matter decomposition. This model has been developed for permanent grasslands in the Swiss Alps under steady-state conditions. The objective of our study was to validate whether this model could be used or adapted, in combination with 13C isotope signatures of SOM, to predict the relative age and stability of SOM fractions in more disturbed agricultural ecosystems.

The present study was carried out on soils collected from six long-term experimental trials (from 12 to 50 years) under different agricultural management practices (e.g. no tillage vs conventional tillage, and mulch, fertilizer, green or animal manure application), located in Austria, Belgium, Kenya and China. Top and subsoil were sampled until 80-100 cm depth. Particulate organic matter (POM) fraction was obtained by wet sieving (> 63μm) after sonification and density separation (<1.8 g cm$-$3). Carbon and nitrogen contents and their stable isotopic ratios (i.e. 15N and 13C) were measured in POM and bulk soils. The mineral associated matter fraction (mOM), as the protected carbon, was calculated by difference to the bulk soil organic carbon. The relative age of the SOM was calculated using the Conen model and preliminary validated by 14C dating.

At all sites, the POM has a higher C:N ratio and a lower δ15N signature compared to the mOM fraction. The POM in top soil layers (<30 cm) has a lower C:N ratio than in deep soil. The C:N ratio and δ15N of POM was influenced by agricultural management. The mOM fraction has 53 to 2063 times longer turnover rate than POM, the relative age of the SOM raised with increasing soil depth. The combination of the above results with δ13C data lead to a more comprehensive understanding of the processes underlying SOM dynamics. Tillage practices increased the bulk δ13C signature of the SOM in the deeper subsoil, suggesting the presence of more stable decomposed materials.

The results of this research seem to indicate that the model, developed for grasslands, can be used to determine the stability of SOM in agricultural ecosystems. The C:N ratio and δ15N signature of the POM and mOM fraction follow the expected model pattern. The isotopic δ13C signature can further enhance the understanding of the processes driving SOM stability.