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Simulating soil C stability with mechanistic systems models: a multisite comparison of measured fractions and modelled pools

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Agriculture, covering more than 30% of global land area, has an exciting opportunity to help combat climate change by effectively managing its soil to promote increased C sequestration. Further, newly sequestered soil carbon (C) through agriculture needs to be stored in more stable forms in order to have a lasting impact on reducing atmospheric CO_2 concentrations. While land uses in different climates and soils require different management strategies, the fundamental mechanisms that regulate C sequestration and stabilisation remain the same. These mechanisms are used by a number of different systems models to simulate C dynamics, and thus assess the impacts of change in management or climate. To evaluate the accuracy of these model simulations, our research uses a multidirectional approach to compare C stocks of physicochemical soil fractions collected at two long-term agricultural sites.

Carbon stocks for a number of soil fractions were measured at two sites (Lincoln, UK; Colorado, USA) over 8 and 12 years, respectively. Both sites represent managed agricultural land but have notably different climates and levels of disturbance. The measured soil fractions act as proxies for varying degrees of stability, with C contained within these fractions relatable to the C simulated within the soil pools of mechanistic systems models1. Using stable isotope techniques at the UK site, specific turnover times of C within the different fractions were determined and compared with those simulated in the pools of 3 different models of varying complexity (RothC, DayCent and RZWQM2). Further, C dynamics and N-mineralisation rates of the measured fractions at the US site were assessed and compared to results of the same three models.

The UK site saw a significant increase in C stocks within the most stable fractions, with topsoil (0-30cm) sequestration rates of just over 0.3 tC ha-1 yr-1 after only 8 years. Further, the sum of all fractions reported C sequestration rates of nearly 1.0 tC ha-1 yr-1. At the US site, however, topsoil C sequestration was less consistent noting considerable variation over the 12 years of measured data. Both sites showed noteworthy discrepancies when model-simulated C was compared with measured C. While all three models were able to simulate the bulk C stocks within reasonable degrees of uncertainty, the accuracy broke down considerably when this bulk soil was split into fractions/pools. Using the data collected and accounting for the differences in model structure, we present potential next steps in model development as well as the variables that should be measured when aiming to reduce the uncertainties inherent in mechanistic systems models.

References

1 – Zimmermann et al., 2007. Measured soil organic matter fractions can be related to pools in the RothC model. European Journal of Soil Science, 58:658–667.