Linking temperature sensitivities of soil enzymes to temperature responses of different organic matter pools in the DAISY model

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Soil organic carbon (SOC) losses under a changing climate are driven by the temperature sensitivity of SOC mineralization (usually expressed as Q_{10}, the multiplier of activity with 10 °C temperature increase). The activation energy theory (AET) suggests that, due to higher activation energies, the more complex the carbon, the higher is mineralization Q_{10}. However, studies on Q_{10} have been inconsistent with regard to AET. Measurements of potential soil enzymes activity Q_{10} even contradicted AET: Phenoloxidase (representing complex carbon) had consistently lower Q_{10} than the more labile xylanase and glucosidase. This study used two approaches of examining Q_{10} in SOC modeling: 1) Bayesian calibration (BC) and 2) using different measured enzyme Q_{10} as proxies for mineralization Q_{10} of different SOC pools. The SOC model was DAISY (S. Hansen et al., 2012). BC informed Q_{10} by field measured data, while the second approach tested if directly using enzyme Q_{10} (of phenoloxidase, glucosidase and xylanase) for DAISY pools improved simulation results. Both approaches used the temperature sensitive measurements of CO_2 evolution and soil microbial biomass. The measured enzyme Q_{10} were from field manipulation experiments with bare fallow and vegetated plots in the two regions of Kraichgau and Swabian Jura in Southwest Germany. The enzyme-derived Q_{10} were used for modelling those fields and furthermore for in situ litterbag decomposition experiments at 20 sites in the same region. Two further laboratory experiments with temperature manipulation were included: an incubation of the field residues into soil and an incubation of bare soil from the start and year 50 of a long duration bare fallow (from Ultuna). The BC made use of CO_2 and microbial data to inform about the range of Q_{10} of different carbon pools for the individual experiments and combined data.

The BC of the residue incubation experiment constrained Q_{10} for metabolic (~3) and structural litter (~2). Estimated 95% credibility intervals did not overlap. The BC for Ultuna could constrain the slow and fast SOC pool with Q_{10} ~2.8 and ~3, respectively, but credibility intervals of both pools

overlapped. The Q_{10} of field experiments, which had most abundant data, could not be constrained by BC, probably because their annual temparature variability was too low. However, the model errors of the field experiment could be reduced by the second approach, when the Q_{10} of phenoloxidase was used for to the structural litter pool as well as for the fast and slow SOC pools. Thus regional enzyme Q_{10} improved the model fit but only for regional simulations. Therefore, they could be useful proxies when natural temperature range is too small to inform temperature sensitivity by BC. Any trends found in this study contradicted AET, both from measured enzymes and BC of the incubation experiments. This calls for alternative Q_{10} hypotheses and the need for individual Q_{10} values for different SOC pool rather than a general one. BC approaches would benefit from a wider temperature range of field experiments and understanding what causes variable enzyme Q_{10} could help to improve future SOC models.