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Modelling climate-substrate interactions in microbial SOC decomposition

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Soil organic carbon (SOC) is the largest terrestrial carbon pool. However, it is still uncertain how it will respond to climate change in the 21st century. Especially SOC losses due to soil warming are a source of uncertainty. It is generally accepted that microbially driven SOC decomposition will increase with warming, provided that sufficient assimilable substrate is available. Sorption to mineral surfaces or the soil moisture-dependent diffusion of substrates to microbial cells can limit substrate availability. Substrate supply is therefore a potentially rate limiting step for the temperature response of SOC decomposition.

In SOC decomposition models, the combined effects of temperature and soil moisture on the decomposition rate can be represented by the Dual Arrhenius Michaelis-Menten (DAMM) model (Davidson *et al.* 2012). For any substrate (S), it describes the reaction velocity V = Vmax [S]/(kM_S+[S]), where [S] is the substrate concentration and kM_S is the half-saturation constant. The maximum reaction velocity, Vmax, is temperature dependent and follows an Arrhenius function. Also, a positive correlation between temperature and kM-values of different enzymes has been empirically shown, with Q_{10} values ranging from 0.71-2.8 (Allison et al., 2018). As kM_S appears in the denominator of the Michaelis-Menten equation, an increase in kM_S leads to a lower reaction velocity (V) and V would become less temperature sensitive at low substrate concentrations.

Besides temperature, substrate concentration [S] depends on soil moisture content. In a dry soil, substrate diffusion to the microbial surface is limited, whereas in a very wet soil, reduced oxygen availability can lower the reaction velocity (V). Changes in substrate supply in drying/(re)wetting soils coincide with changes in temperature which directly interact with the temperature sensitivities of Vmax and kM_S. These interactions can have consequences for decomposition rates in the topsoil versus the deeper soil, since substrate concentrations and temperature are generally higher in the topsoil, but moisture could be more important for substrate limitation. In contrast, in the deep soil, soil moisture might be more available but substrate concentrations (and potentially soil temperatures) might be lower.

This study focuses on this interaction between climate change and substrate availability by comparing two model experiments: 1) a modelling experiment where only Vmax is temperature

sensitive and 2) one where both Vmax and kM_S are temperature sensitive. We also investigate the consequences of the counteracting temperature sensitivities of Vmax and kM_S among a substrate gradient, and at different soil temperatures and soil moisture ranges. Finally, we look at dynamic changes in substrate supply, temperature sensitivities and changes in soil moisture and their effects on SOC decomposition in a microbially explicit dynamic SOC decomposition model which also includes organo-mineral interactions.