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Physically based model of organic carbon mineralization under varying soil environmental conditions

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In recent years, it is increasingly becoming clear that soil encironmental conditions exert significant control on the rate of organic matter mineralization. However, the exact mechanistic coupling between hydrological and biogeochemical processes that govern the rate of mineralization remains poorly understood. Here we present a modification of the conventional exponential decay model of organic matter mineralization ($dC/dt = -kC$) by incorporating the effects of water content and temperature. First, we redefine the instantaneous labile carbon concentration term as accessibility of the bulk carbon to decomposers. This in turn is related to water saturation (S); with the end members being that all the carbon is accessible in saturated soil and none of the carbon is accessible in completely dry soil ($C \propto S$). The decay constant is refined as a product of several environmental and biogeochemical factors that regulate rate of mineralization ($k = k_W k_A k_T k_B ...$, where the W, A, T, and B denote water, oxygen, temperature, and biology, respectively). This modeling framework is tested by comparison with a large set of experimental data. One important advantage of this physically based model is that it can be used to describe carbon mineralization rate under dynamic soil environmental conditions (such as temperature and water content fluctuations). In addition, the model accurately captures the complex mineralization pattern in aggregated soils that are characterized by multiple classes of pores (e.g., inter- and intra-aggregate pores).