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Sensitivity of soil organic matter decomposition to simultaneous changes in temperature and moisture

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Soil organic matter decomposition depends on multiple factors that are being altered simultaneously as a result of global environmental change. For this reason it is important to study the overall sensitivity of soil organic matter decomposition with respect to multiple and interacting drivers. Here we present an analysis of the potential response of decomposition rates to simultaneous changes in temperature and moisture. To address this problem, we first present a theoretical framework to study the sensitivity of soil organic matter decomposition when multiple driving factors change simultaneously. We then apply this framework to models and data at different levels of abstraction: 1) to a mechanistic model that addresses the limitation of enzyme activity by simultaneous effects of temperature and soil water content, the latter controlling substrate supply and oxygen concentration for microbial activity; 2) to different mathematical functions used to represent temperature and moisture effects on decomposition in biogeochemical models. To contrast model predictions at these two levels of organization, we compiled different datasets of observed responses in field and laboratory studies. Then we applied our conceptual framework to: 3) observations of soil respiration at the ecosystem level; 4) laboratory experiments looking at the response of heterotrophic respiration to independent changes in moisture and temperature; and 5) ecosystem-level experiments manipulating soil temperature and water content simultaneously. The combined theoretical and empirical evidence reviewed suggests: first, large uncertainties still remain regarding the combined controls of temperature and moisture on decomposition rates, particularly at high temperatures and the extremes of the soil moisture range; second, the highest sensitivities of decomposition rates are likely in systems where temperature and moisture are high such as tropical peatlands, and at temperatures near the freezing point of water such as in soils under freeze-thaw cycles. These regions also exhibit the largest differences in projected changes in decomposition rates among different models. Third, the lowest sensitivity of decomposition rates to changes in temperature and moisture is expected in soils with temperatures well below the freezing point. Uncertainty in models can be reduced if some of the functions representing the effects of temperature and moisture on decomposition can be discredited based on empirical observations or experiments.