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Substrate heterogeneity and environmental variability in the decomposition process

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Soil organic matter is a complex mixture of material with heterogeneous biological, physical, and chemical properties. However, traditional analyses of organic matter decomposition assume that a single decomposition rate constant can represent the dynamics of this heterogeneous mix. Terrestrial decomposition models approach this heterogeneity by representing organic matter as a substrate with three to six pools with different susceptibilities to decomposition. Even though it is well recognized that this representation of organic matter in models is less than ideal, there is little work analyzing the effects of assuming substrate homogeneity or simple discrete representations on the mineralization of carbon and nutrients. Using concepts from the continuous quality theory developed by Göran I. Ågren and Ernesto Bosatta, we performed a systematic analysis to explore the consequences of ignoring substrate heterogeneity in modeling decomposition. We found that the compartmentalization of organic matter in a few pools introduces approximation error when both the distribution of carbon and the decomposition rate are continuous functions of quality. This error is generally large for models that use three or four pools. We also found that the pattern of carbon and nitrogen mineralization over time is highly dependent on differences in microbial growth and efficiency for different qualities. In the long-term, stabilization and destabilization processes operating simultaneously result in the accumulation of carbon in lower qualities, independent of the quality of the incoming litter. This large amount of carbon accumulated in lower qualities would produce a major response to temperature change even when its temperature sensitivity is low. The interaction of substrate heterogeneity and temperature variability produces behaviors of carbon accumulation that cannot be predicted by simple decomposition models. Responses of soil organic matter to temperature change would depend on the interacting effects of the sensitivity of different pools to decomposition, the amount of carbon stored in the pools, the variability of climatic drivers, and the degree and nature of the nonlinearities in the system.