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Entropy of biogeochemical compartment models: complexity and information content as a tool for model development

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Most soil organic matter decomposition models consist of a number of compartments describing the dynamics of substrate and microbial biomass pools. The fluxes of mass between the compartments are usually described by a system of ordinary differential equations, in which the number of compartments and the connections among them define the complexity of the model and the number of biological processes that need to be described. With this approach, it is difficult to determine the level of detail that is required to describe a given system, and it is also difficult to compare models against each other due to large differences in their level of complexity. Here, we propose entropy as a tool to determine the level of complexity required to describe a biogeochemical system and to compare the information content of different models.

Instead of entire masses on bulk soil level, we look at such models from the point of view of a single particle on the molecular level. This particle enters the system, cycles through it, and leaves it at some point later in time, thereby following a path through the system. We think of this path as a particular stochastic process, a Markov renewal process.

If we consider this path as a random variable in a path space, its Shannon information entropy describes its information content, i.e. how much we learn when we observe the entire path of a particle traveling through the system. In other words, it tells us how hard it is to predict this path and thus how much we do not know about what is going to happen to one single particle. The entropy as a measure of model complexity can help us to decide whether a model is not complex enough to represent the information that we have about a system or whether it is too complex. The concept of maximum entropy provides a powerful tool to develop unbiased models, i.e. models that contain the exact amount of information that we have about the system. In addition, differences between a soil organic matter decomposition model's entropy and the maximum entropy might allow us to identify so far unknown important underlying processes of the system described by the model.