Microbial Enzymes in the Soil:
The Microscopic Drivers of Global Carbon and Nutrient Recycling

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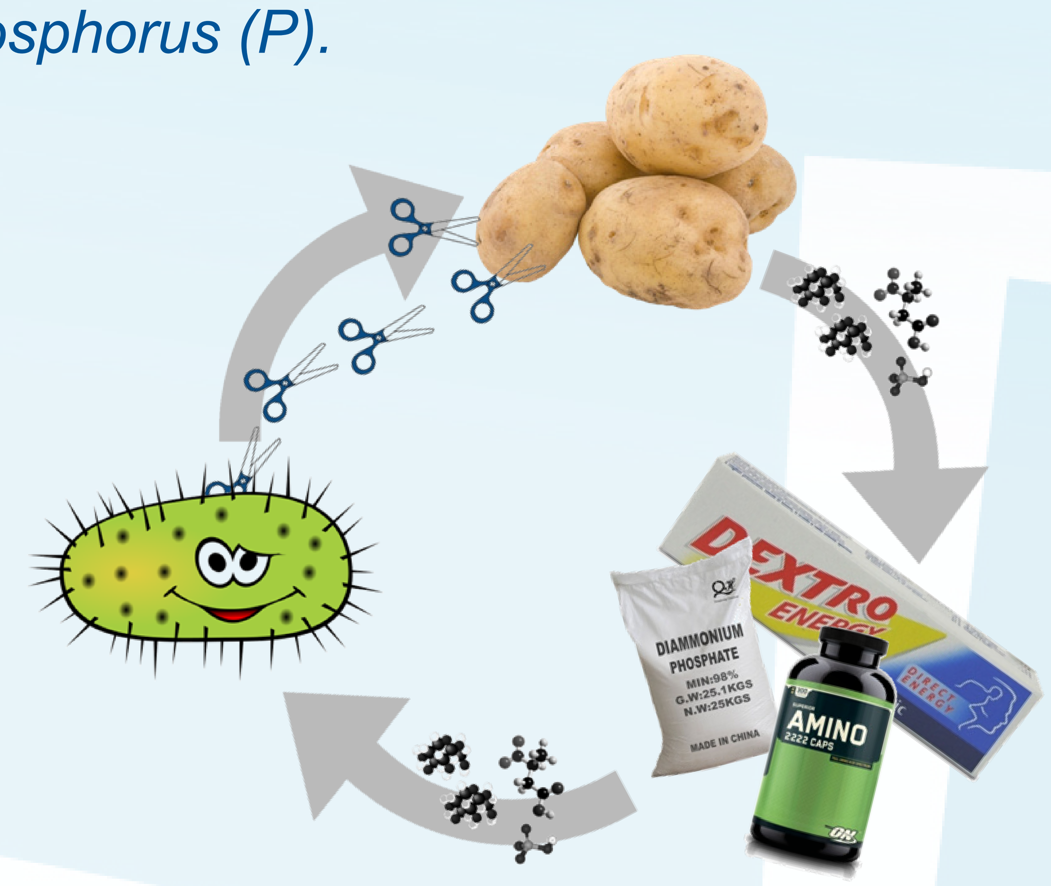
Microbes produce extracellular enzymes to decompose organic material (e.g. dead plants) into accessible nutrient elements: carbon (C), nitrogen (N) and phosphorus (P).



Background

Soil carbon turnover is a particularly weak link in our understanding of ecosystem responses to climate change, such as the potential for carbon sequestration or release. Because microbial enzyme production is the fundamental driver of carbon and nutrient recycling in the soil, better understanding and improved models of this process are essential.

Model

Microbes take up simple nutrients (C, N and P), which are used either for biomass growth, or to produce extracellular enzymes in order to decompose complex resources into accessible (simple) nutrients. The microbes optimize the proportions of different biomass components and enzyme production to maximize their growth rate.

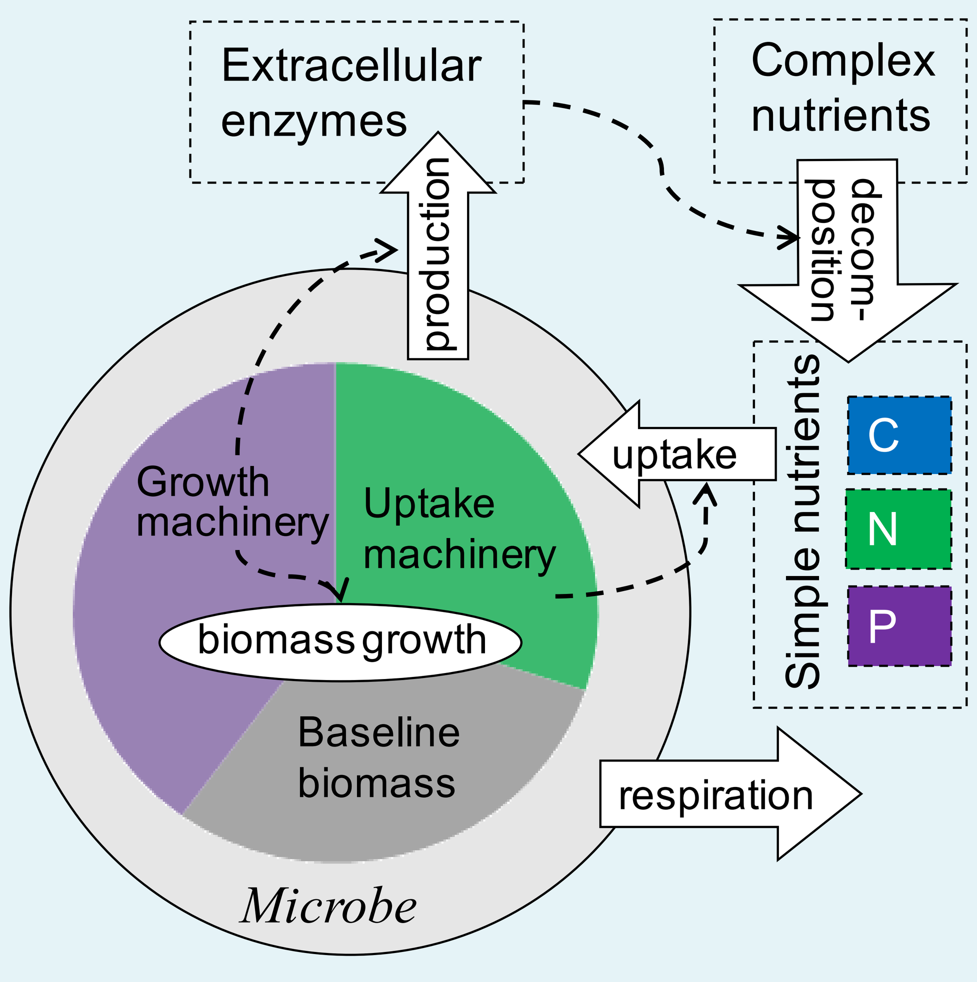


Figure 1. Model components

Microbial biomass consists of baseline biomass, uptake machinery and growth machinery (e.g. RNA). The biomass fraction of uptake and growth machinery determines the maximum capacity for uptake and production (biomass + enzymes), respectively. The biomass fractions, each with a fixed C:N:P ratio, also determine the total biomass stoichiometry. To handle co-limiting resources, growth is modeled based on the synthesizing unit concept (as done in Franklin et al. 2011*).

Three types of extracellular enzymes are considered, defined by the element they target: C-, N-, and P-acquiring enzymes. The effect of each enzyme depends on its production rate, its efficiency, and the availability of complex resource.

Findings

- Extracellular enzymes are the tools microbes use to fulfill their roles as material recyclers in the global carbon and nutrient cycles.
- Increased N and P concentration in plant material promotes enzyme production, which increases decomposition and nutrient recycling.
- Adding accessible carbon (e.g. glucose) to microbes growing on new plant litter suppresses enzyme production and decomposition.
- Adding accessible carbon to old recalcitrant material (e.g. humus) increases enzymatic decomposition, releasing nutrients and carbon through a priming effect.

Addition of accessible nutrients may suppress decomposition

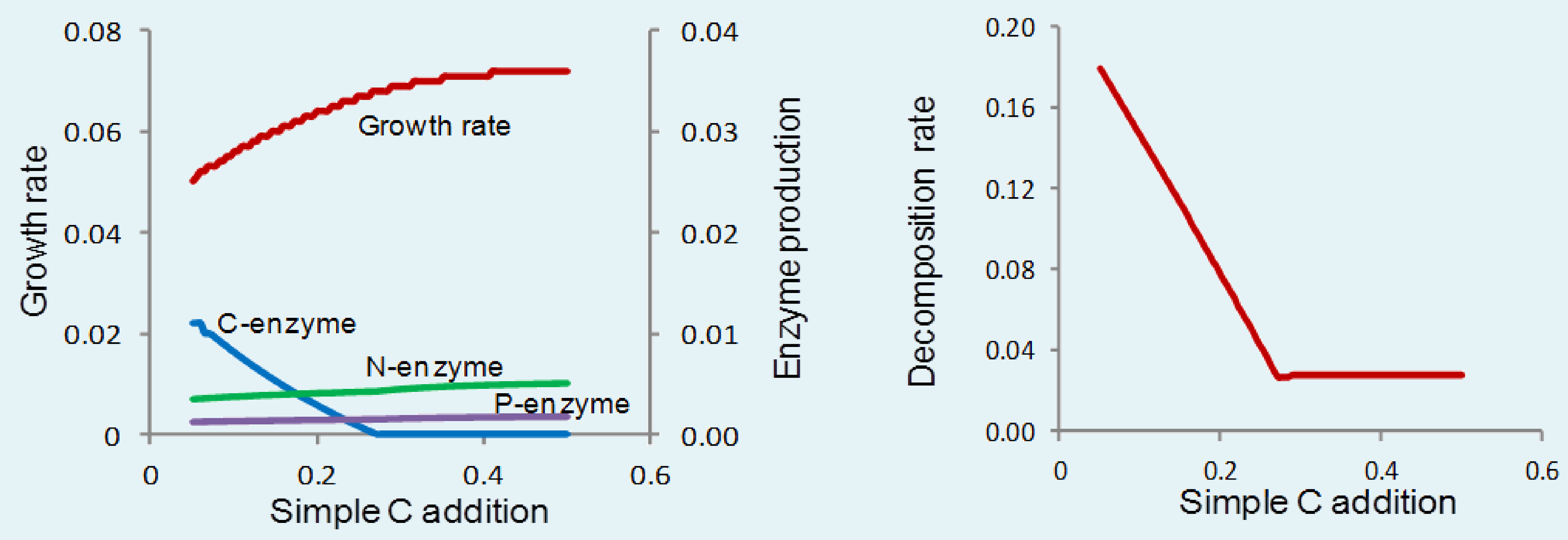


Figure 2. Adding accessible (simple) carbon (C) to relatively intact organic material (plant material with C:N:P ratio = 100:6:1) increases microbial growth rate but reduces the production of C-acquiring enzymes and therefore decomposition rate of the organic material.

Addition of accessible carbon can increase decomposition (priming)

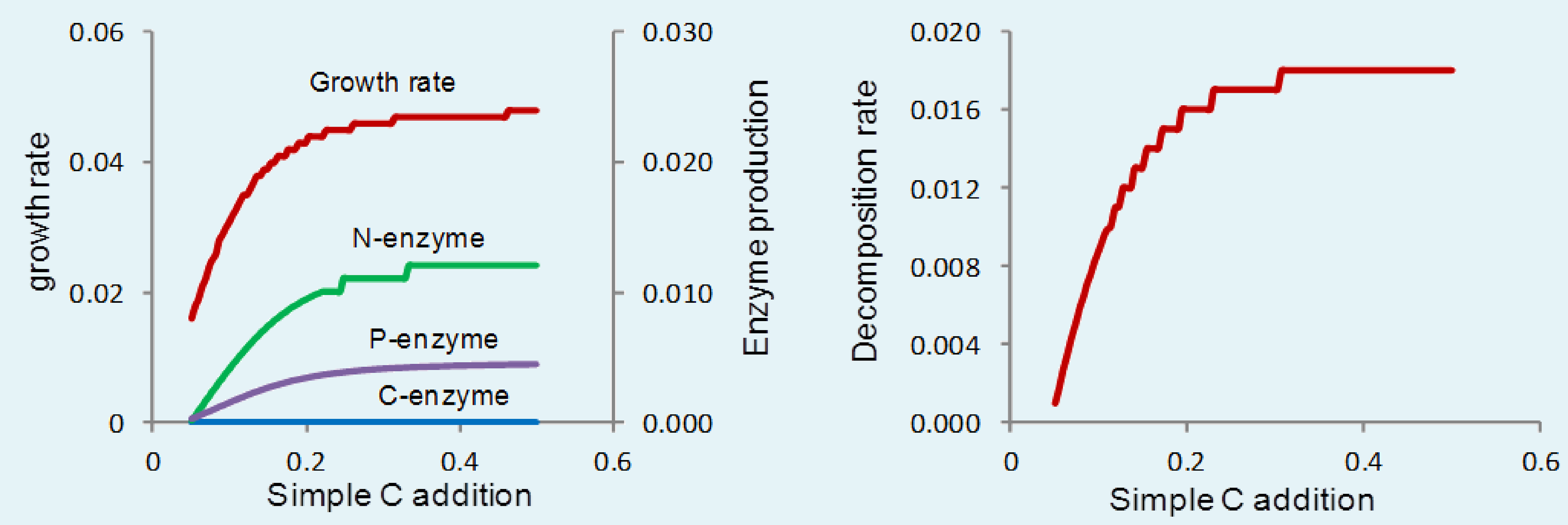


Figure 3. Adding accessible (simple) C to low-C recalcitrant material increases the production of N- and P-acquiring enzymes, which increases decomposition rate. The low-C recalcitrant resource had C:N:P = 25:6:1 and the enzyme decomposition efficiency was reduced by a factor 10 compared to the plant material in fig. 2.

Contact and further info

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***Reference:**
Franklin, O., E. K. Hall, C. Kaiser, T. J. Battin, and A. Richter. 2011. Optimization of biomass composition explains microbial growth-stoichiometry relationships. American Naturalist 177:e29-e42.