Eco-enzymatic stoichiometry and enzymatic vectors in decaying litter reveal differential C, N, P dynamics along a land-use gradient

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Introduction

At a global scale, eco-enzymatic ratios were shown to provide a functional measure of the threshold at which control of community metabolism shifts from nutrient to carbon limitation[1]. However at a finer scale, the controls of nutrient availability on microbial community structure and associated enzyme production are still poorly understood.

Microbial decomposer communities cope with substrates that vary considerably in C:N:P stoichiometry compared to that of their own biomass. Changes in relative abundances of extracellular enzymatic activities (EEA) involved in C, N, and P cycling should reflect relative resource acquisition by these communities.

Objectives

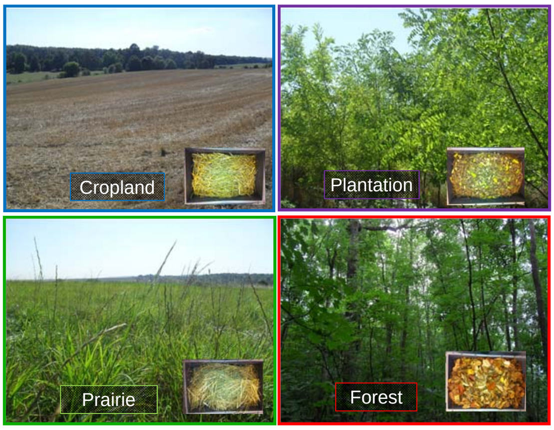
Evaluate the eco-enzymatic theory using a land-use gradient under controlled conditions.

Use length and angle of enzyme vectors[2] to explore relationships between EEA and mineralization rates, microbial metabolism and community structure.

Material & Methods

Full reciprocal transplant experiment

Litter and soil samples were collected in a one-hectare plot with a common soil substratum



4 litter species
(*Fagus sylvatica, Triticum aestivum, Robinia pseudoacacia, Festuca arundinacea*)

x

4 soils
(*Forest, Culture, Plantation, Grassland*)

x

3 sampling dates
(*27, 97 and 202 days*)

x

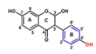
3 replicates

=

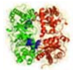
144 microcosms
(20°C, 60% WHC,
10 g C per g of soil)

Dynamic measure of:

- C Respiration
- Mineral N and Olsen P
- Microbial community structure (PLFAs)



- Enzymatic activities



Enzyme **C** (β-glu, α-glu, CBH, xylosidase)
Enzyme **N** and **P** (NAG, LAP, alkaline phosphatase)

Results

$$\text{Vector length} = \sqrt{x^2 + y^2}$$

$$\text{Angle} = Atan2(x, y)$$

x = proportion of C versus P acquiring enzyme activities; y = proportion of C versus N acquiring activities [2,3].

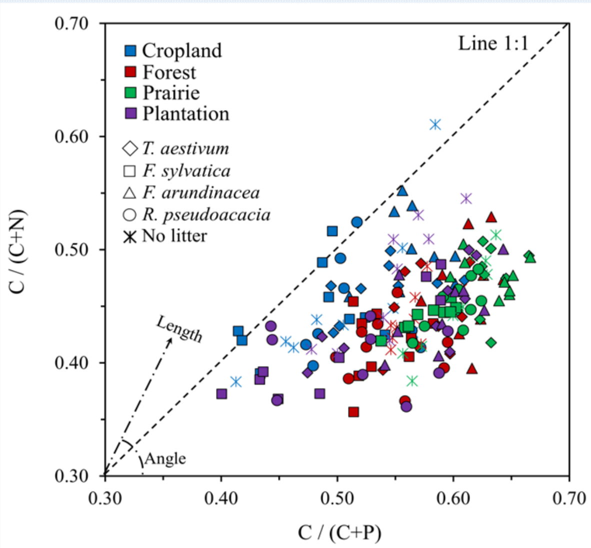


Figure 1: Eco-enzyme stoichiometry of the relative proportions of C to N acquisition versus C to P acquisition. C acquisition is represented by the sum of β-1,4-glucosidase (BG), β-D-cellobiosidase (CBH), β-xylosidase (XYL), and α-1,4-glucosidase (AG); N acquisition is represented by the sum of β-1,4-N-acetylglucosaminidase (NAG) and leucine aminopeptidase (LAP); and P acquisition is represented by alkaline phosphatase (AP) activity

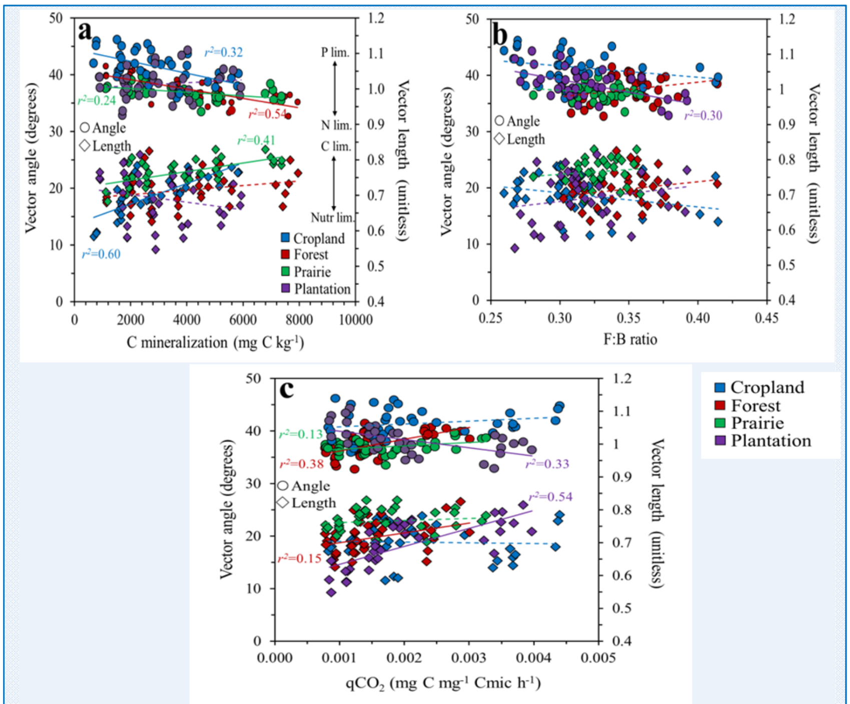


Figure 2: Relationships between vector lengths and angles with a) carbon mineralized, b) Fungi:Bacteria ratio, and c) metabolic quotient according to vector angle (circle) or length (diamond) (litter types combined). Full lines represent significant relationships and associated r[2] values.

Conclusions

- EEA showed that N requirements increased relative to P during litter decay but C requirements increased more rapidly than either N or P in most of these ecosystems.
- Shifts in EEA were related to changes in metabolic quotient (C respired per unit biomass) but not in fungi:bacteria ratios. Functional abilities of soil microbes may be more important than their identity for assessing their resource requirements.
- The use of EEA as a proxy of microbial resource demand improved our understanding of temporal shifts in resource requirements to microbial communities.

References

[1]Sinsabaugh R.L., Hill B.H., Follstad J.J. (2009) Eco-enzymatic stoichiometry of microbial organic nutrient acquisition in soil and sediment. ***Nature*** *462:* 795-798.

[2]Moorhead DL, Sinsabaugh RL, Hill BH, Weintraub MN (2016) Vector analysis of ecoenzyme activities reveal constraints on coupled C, N and P dynamics. ***Soil Biology & Biochemistry*** 93: 1-7

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