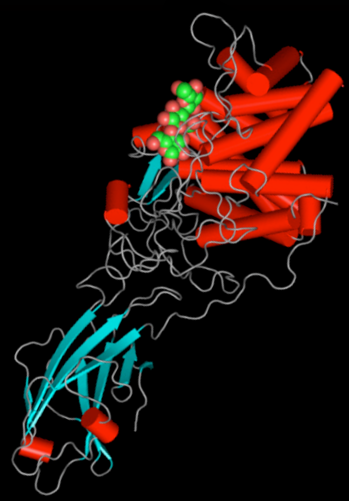

Recent advancements in understanding the ecology of soil extracellular enzymes

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Meg Steinweg

Shawna McMahon

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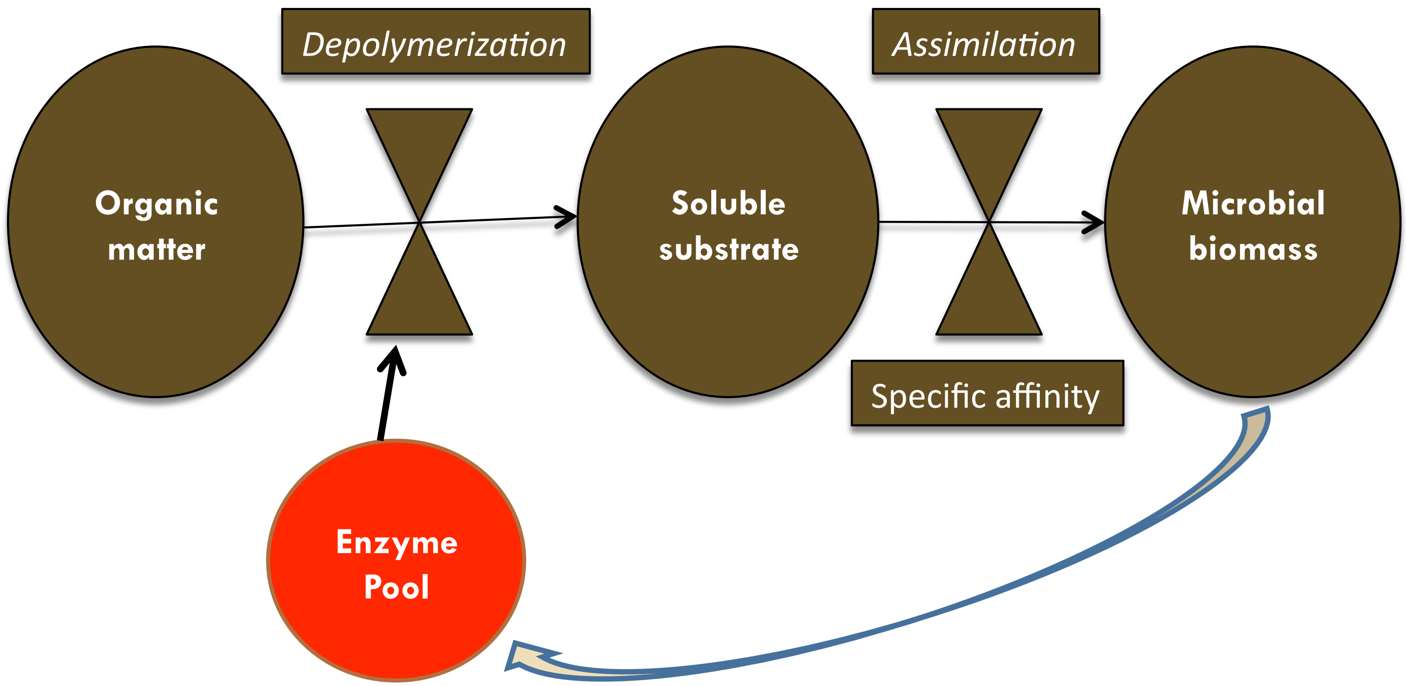
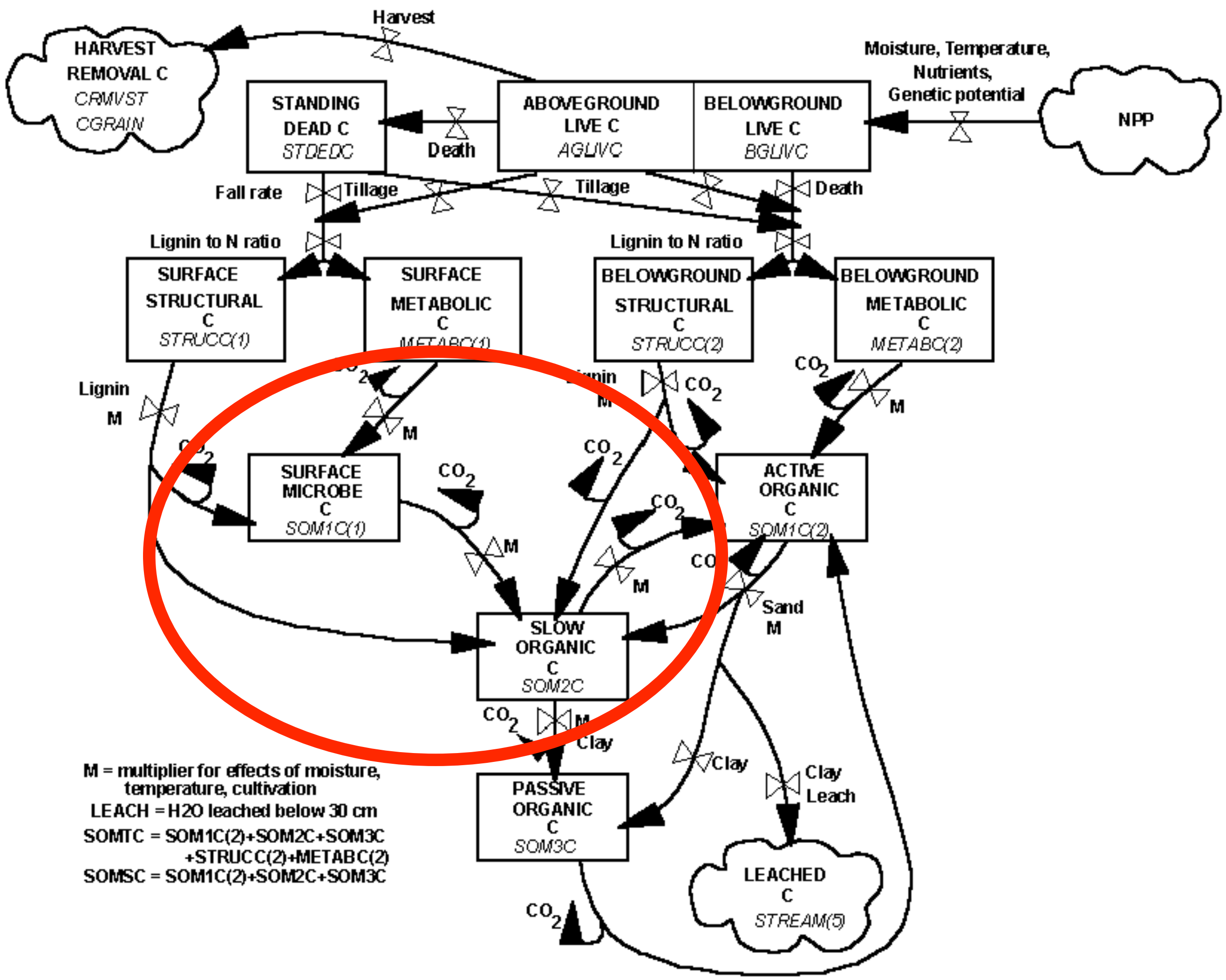
Natural Resource Ecology Laboratory

Enzymes are the proximate drivers of decomposition



Enzymes in current terrestrial ecosystem models



Fundamental questions in soil enzymology

- What factors determine the production of enzymes by plants and microbes?
- What is the turnover time of enzymes after they are released?
- How much activity is maintained by stabilized enzymes?
- ‘Who’ produces different types of enzymes?

How do we interpret patterns in enzyme activities?

- Assumptions:
  - The abundance of enzymes that degrade C-rich substrates reflects the abundance of the substrate
  - The abundance of phosphatase, chitinase, proteases, etc reflect stoichiometric demands for P and N
  - Enzyme activities measured in lab assays indicate potential in situ activities

Three short stories, an anecdote, and a glimpse of the future…

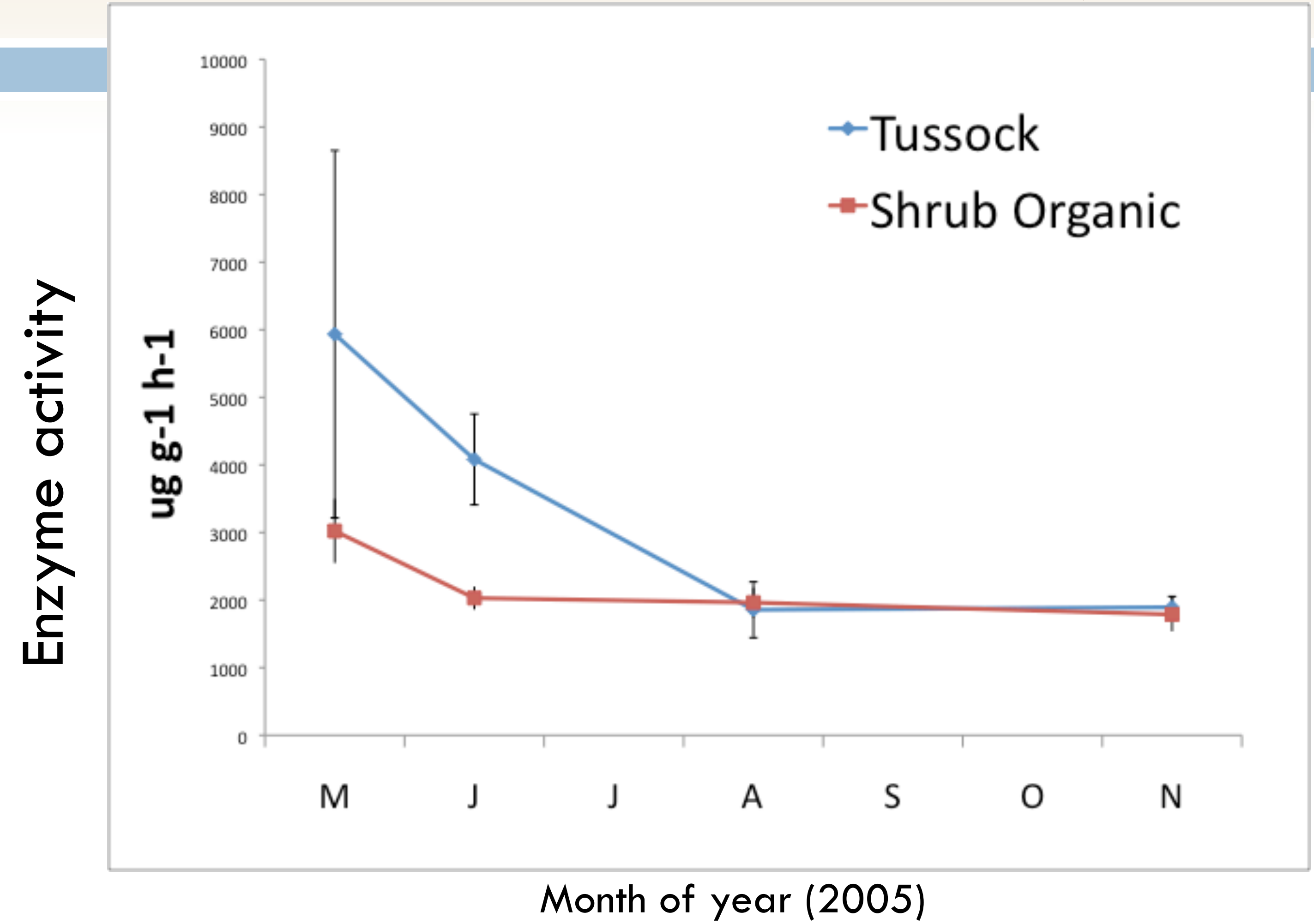
1. Seasonal changes in in-situ activities in Arctic tundra
2. Enzyme dynamics following moisture pulses in a semi-arid grassland
3. Unexpected response of enzymes to drought

- Tannin-enzyme interactions
- Emerging approaches

Story #1: Arctic tundra soils

How do extracellular enzyme activities change seasonally?

B-glucosidase (Lignocellulose)

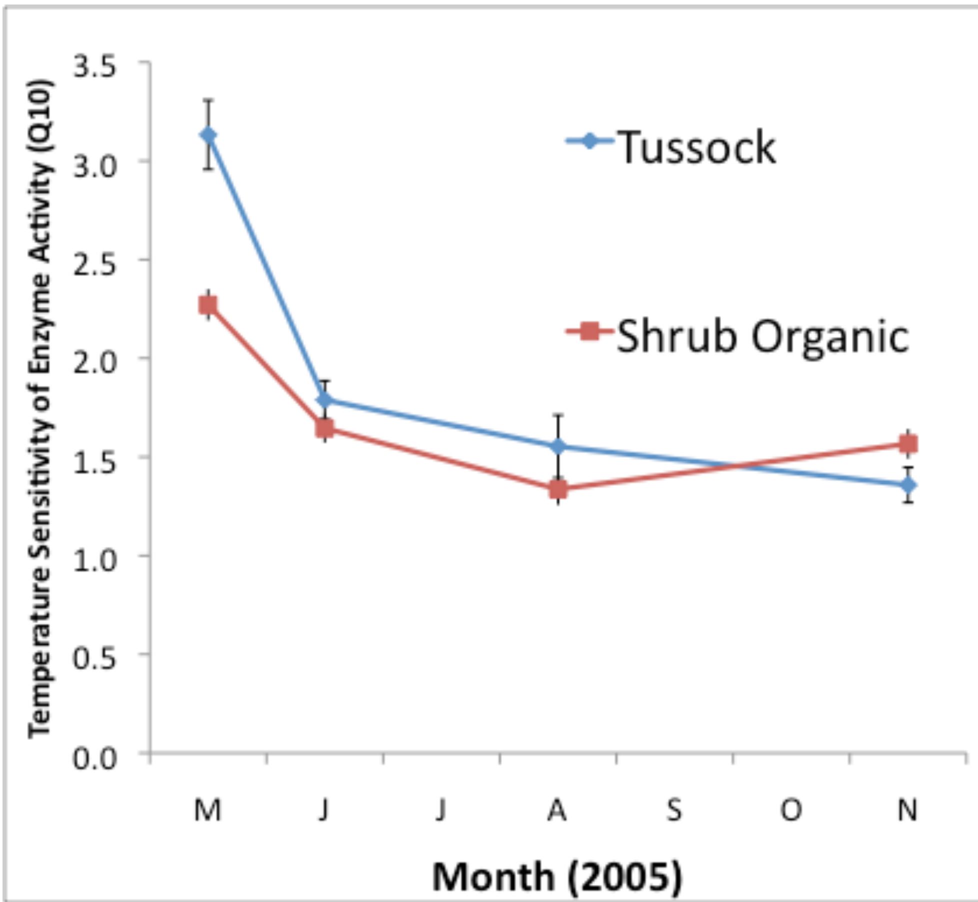


Lignocellulose degrading enzymes peak in late winter.

Wallenstein, McMahon, and Schimel. 2009, Global Change Biology.

Seasonal changes in enzyme temperature sensitivity

B-glucosidase

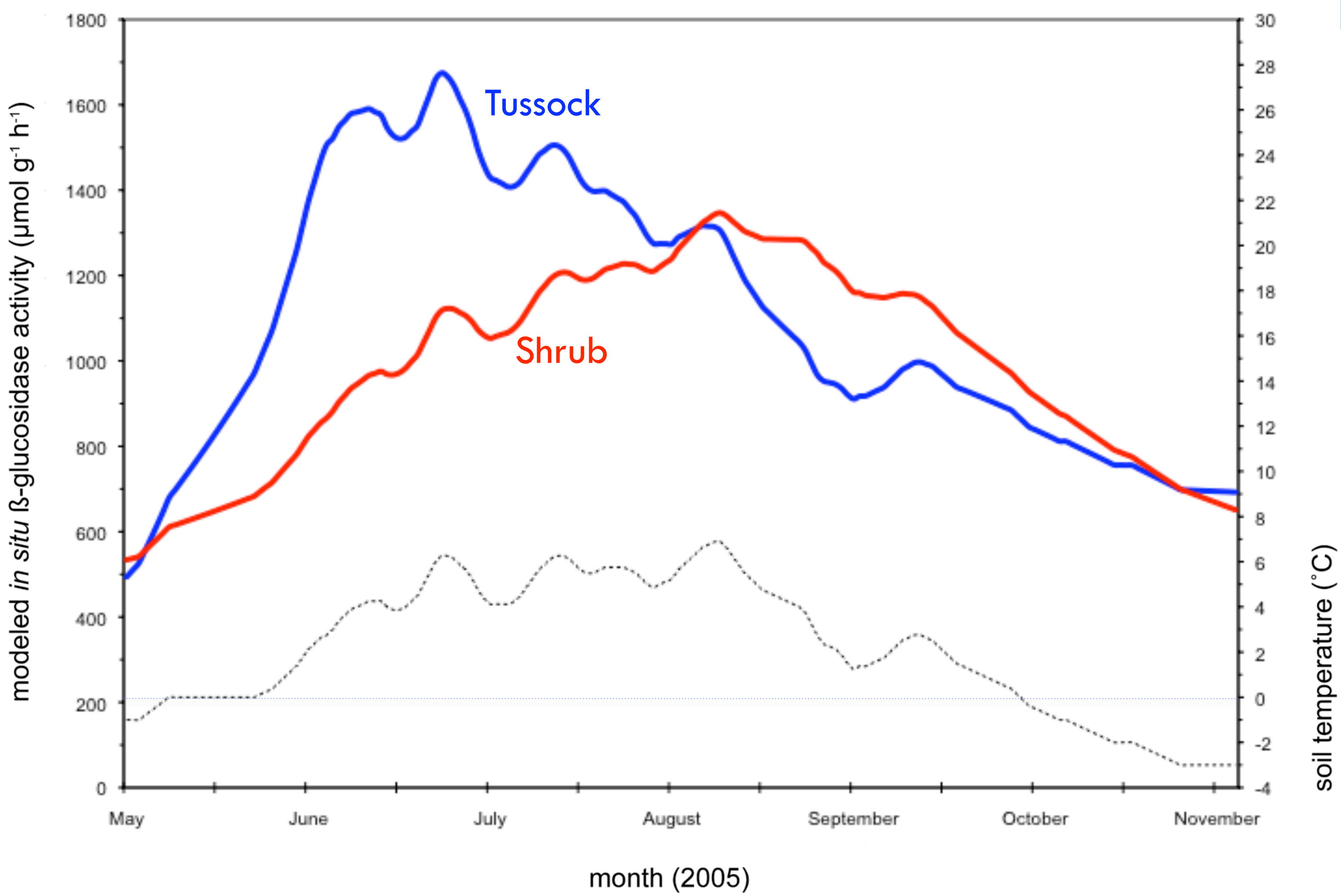


- Winter enzymes are more sensitive to temperature than summer enzymes!

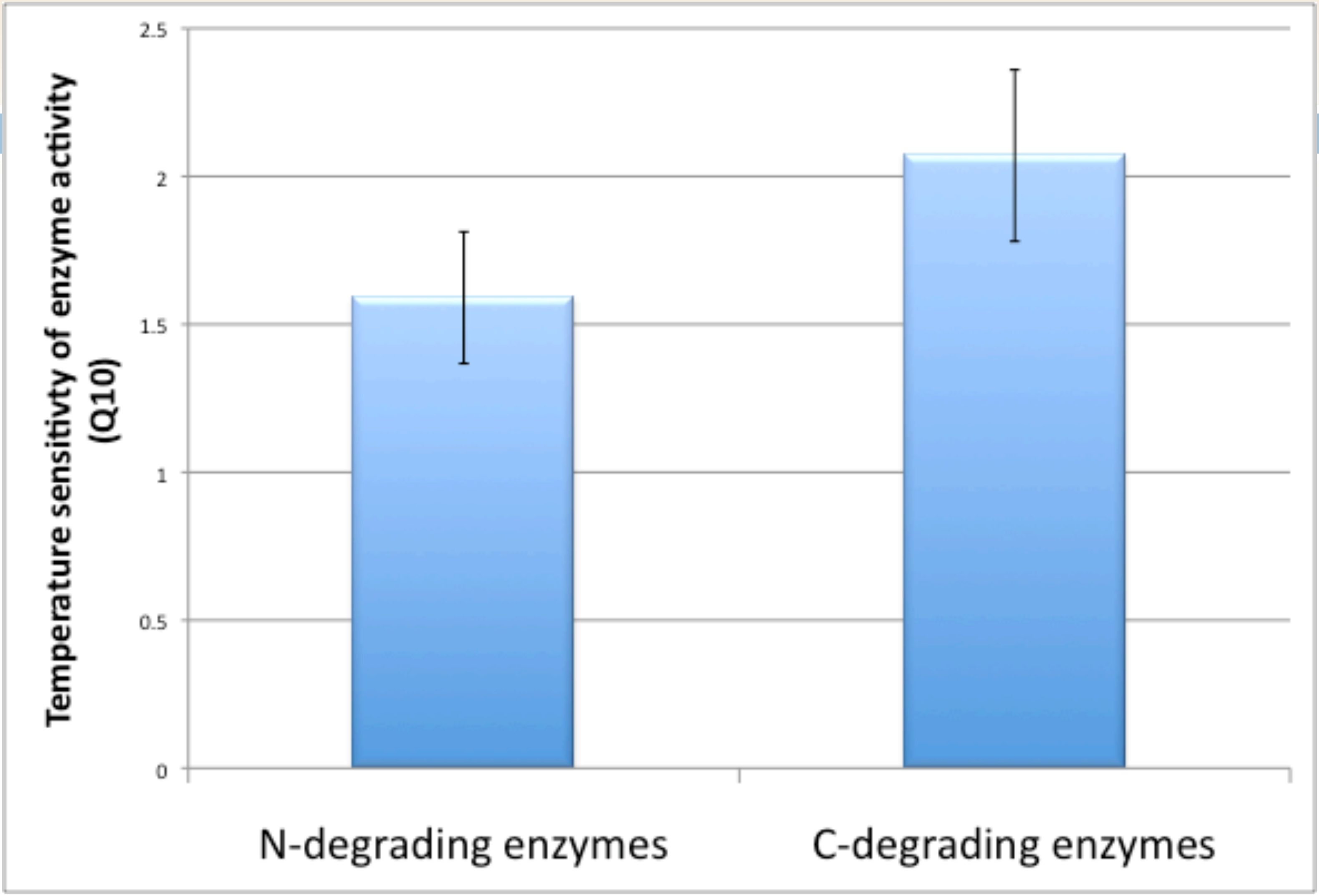
- Suggests that different organisms are producing different iso-enzymes at different times of the year.

Wallenstein, McMahon, and Schimel. 2009, Global Change Biology.

Modeled in-situ enzyme activities



Wallenstein, McMahon, and Schimel. 2009, Global Change Biology.



Wallenstein, McMahon, and Schimel. 2009, Global Change Biology.

Story 1: The Moral

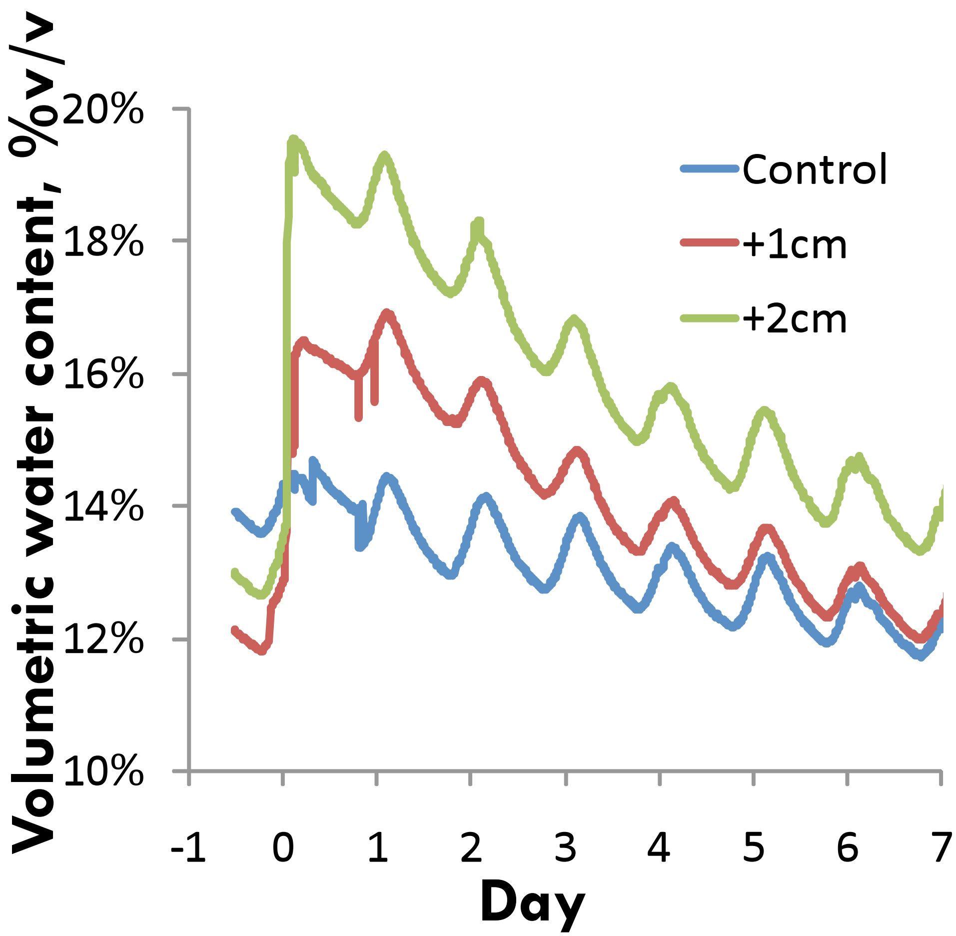
- Temperature is a key driver of in-situ enzyme activities
- Different enzymes may differ in their temperature sensitivity
  - *More labs need to measure enzyme temperature sensitivity!*

Story 2: Semi-arid grassland

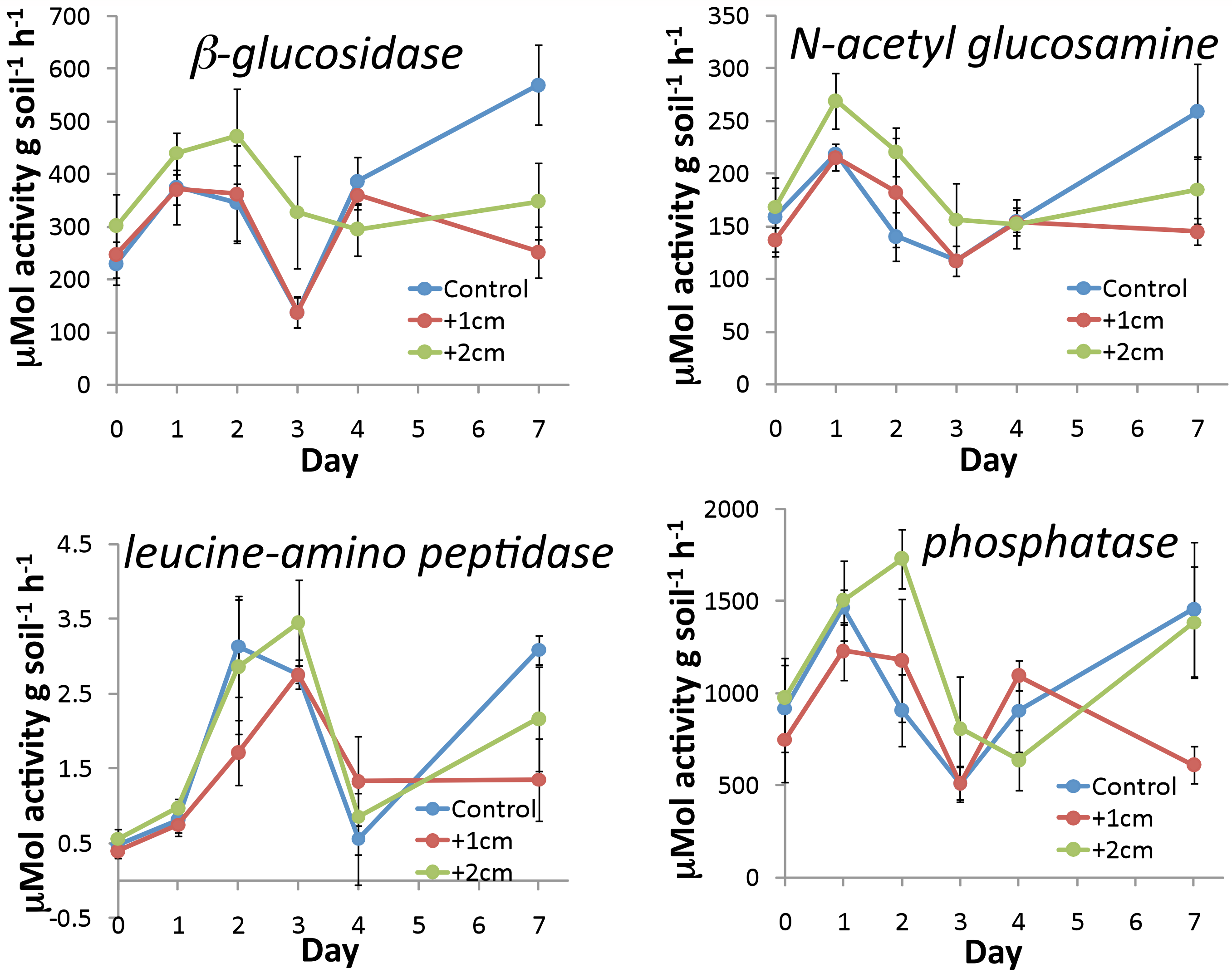
How temporally stable are enzyme activities?

How do enzyme activities change following a precipitation event?

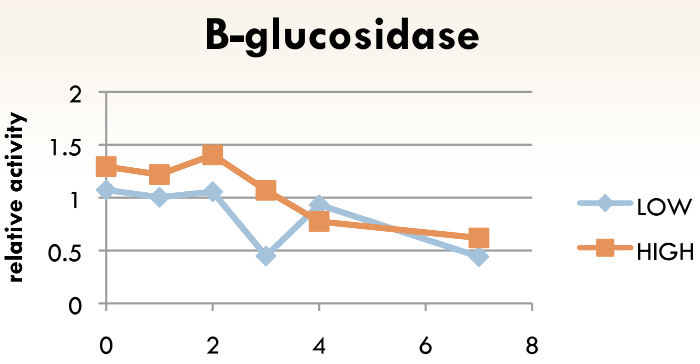
Experimental moisture pulse

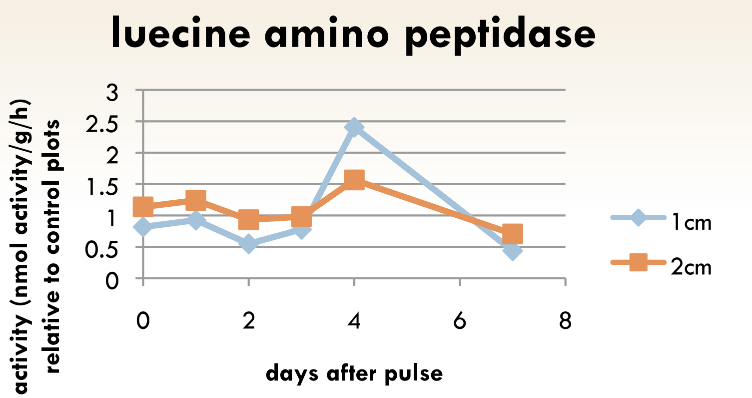


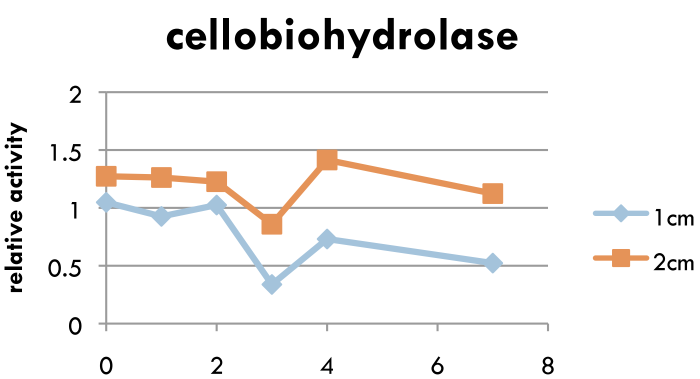
Large daily changes in activity

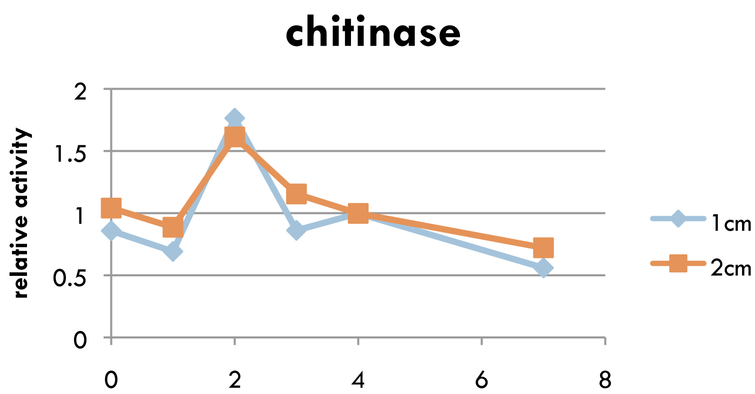


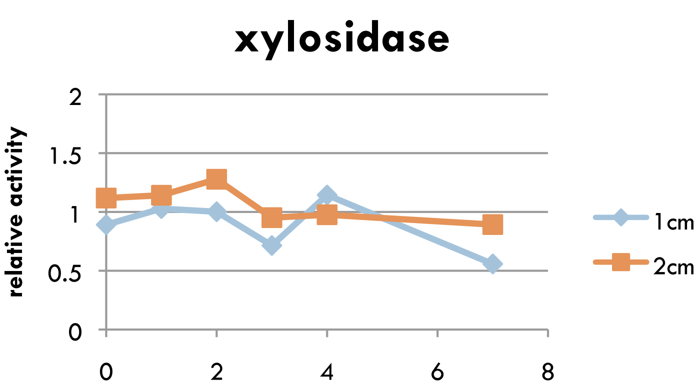
Relative enzyme activities (pulse treatment/control)

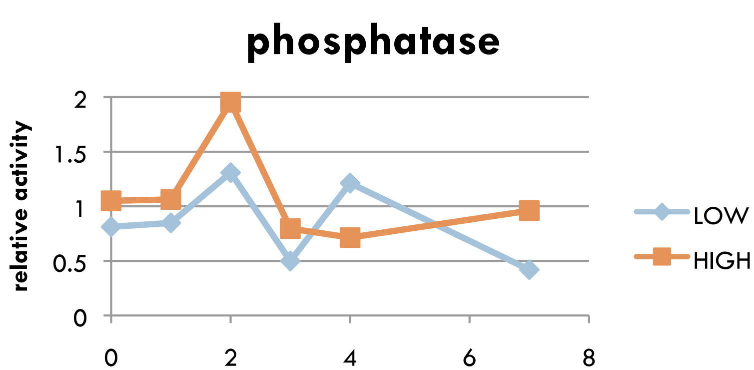












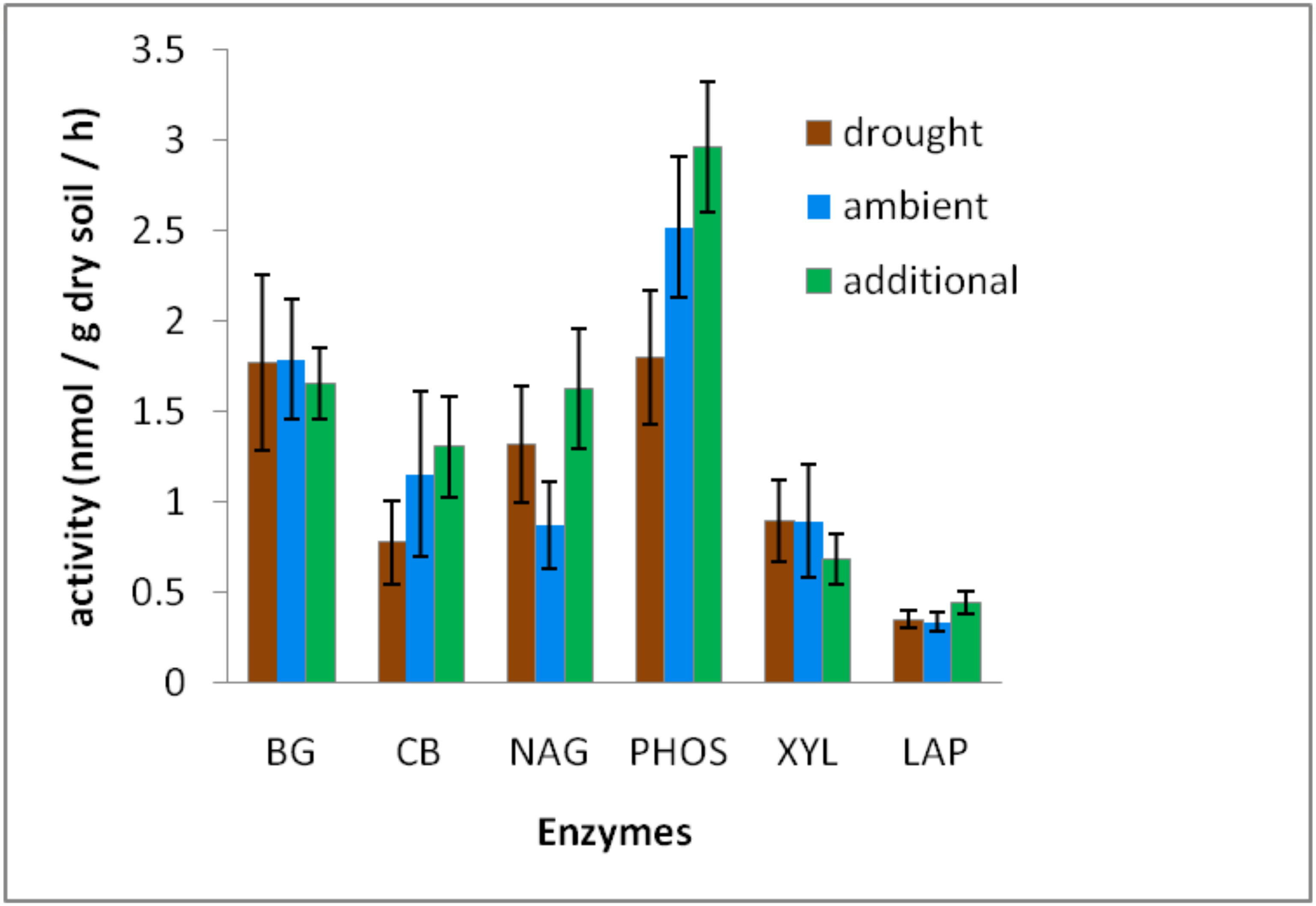
Story 2: The Moral

- Enzyme activities may be more dynamic than assumed
- Temporal dynamics differ by enzyme

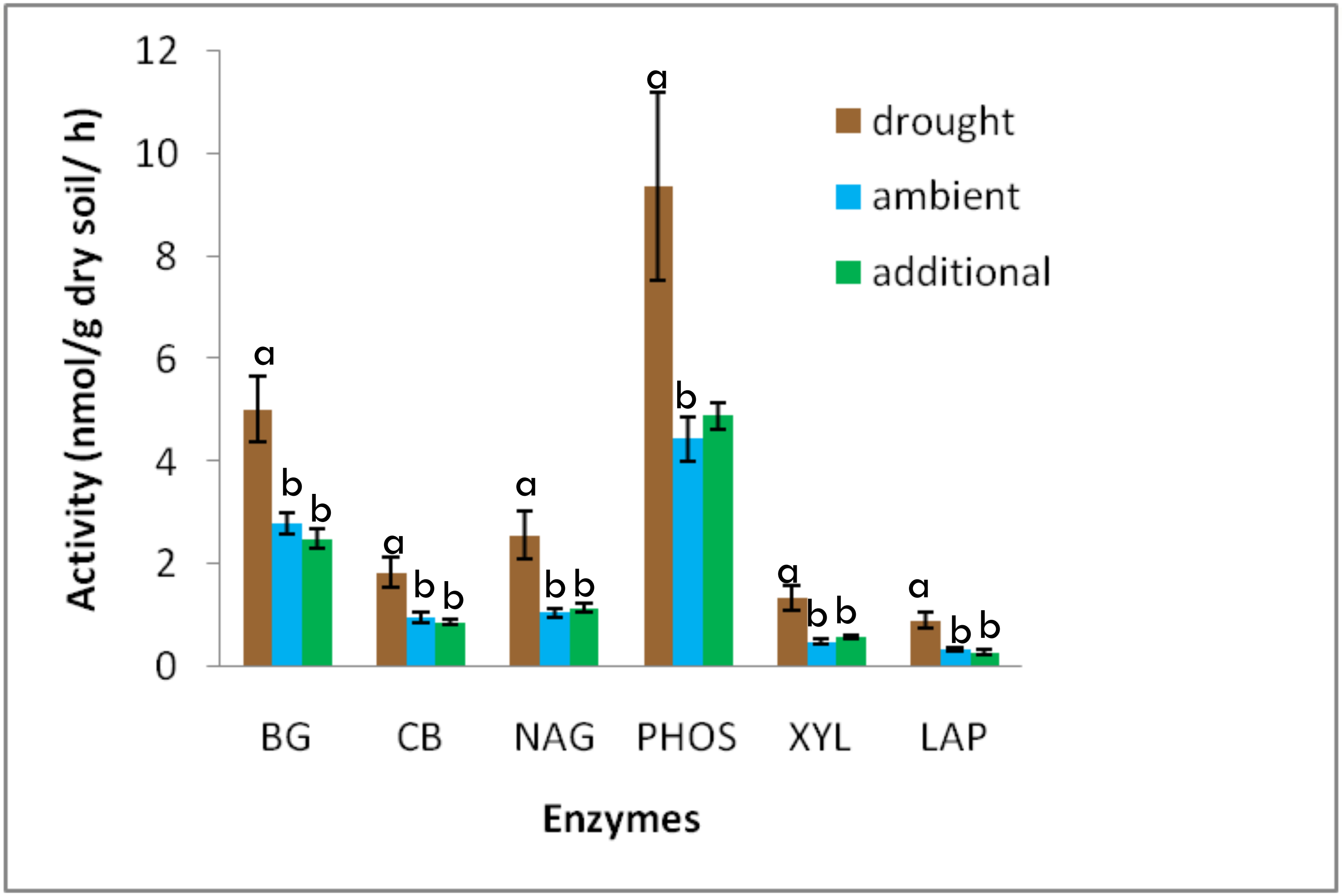
Story #3: Responses to experimental drought

- Boston Area Climate Experiment (BACE)
- 3 Precipitation treatments
  - -50% water, ambient, +50% water
- 4 Temperature treatments
  - ambient, +1, +2, +3°C
- Full factorial design

Enzyme Activity August 2008 0-5cm



Enzyme Activity January 2009, 0-5cm



Letters indicate significant difference between treatments for each enzyme at $p < 0.01$.

So, what's happening in January?

- Higher enzyme activities in drought plots despite lower biomass.

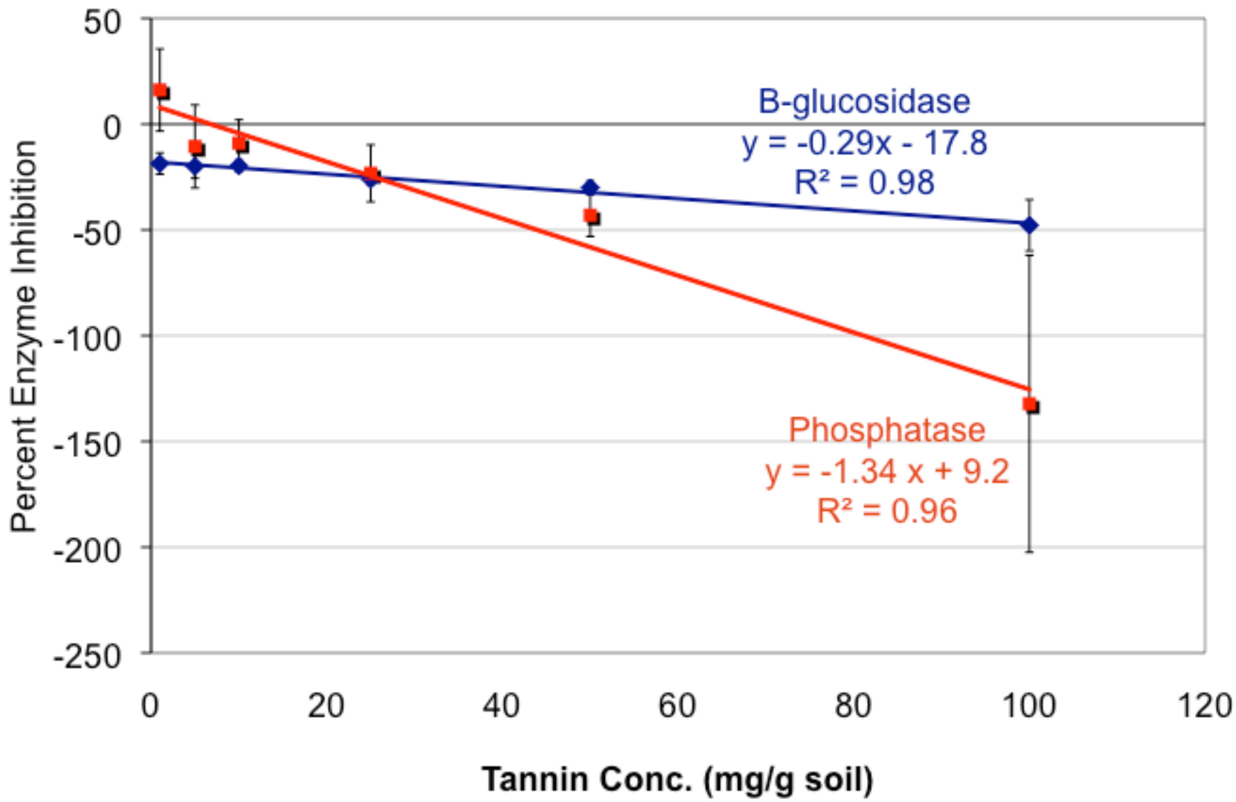
- Working hypothesis: Drought slows the turnover of enzymes, resulting in more enzymes present in the soil

Currently testing this hypothesis using proteomic approaches.

Story 3: The Moral

- Turnover is an important control on enzyme pools (potential enzyme activities)
- Use caution when interpreting enzyme activities!

An anecdote:
Inhibition of soil enzymes by Artemesia tannins



A glimpse of the future: Emerging techniques and approaches

- In-situ measurements
- Proteomics
- Modeling

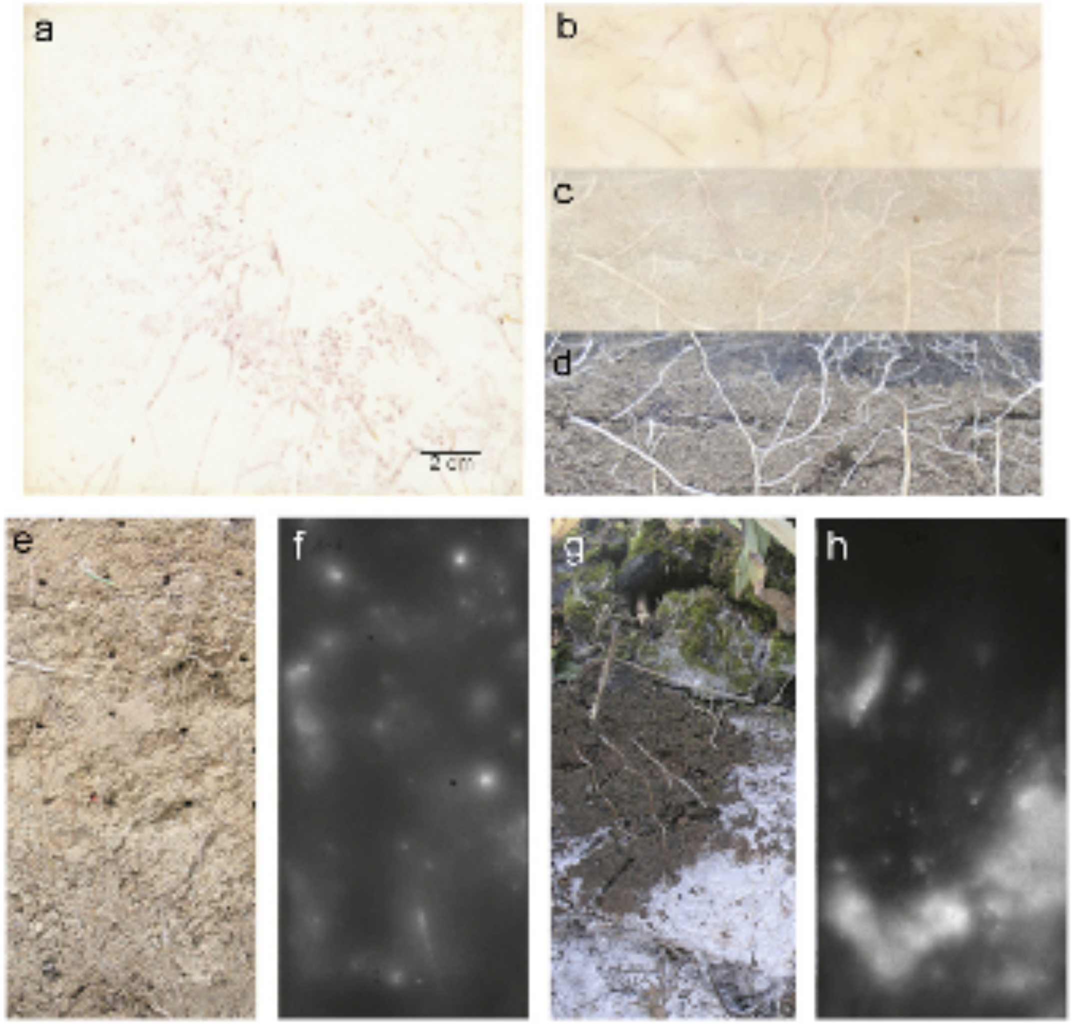
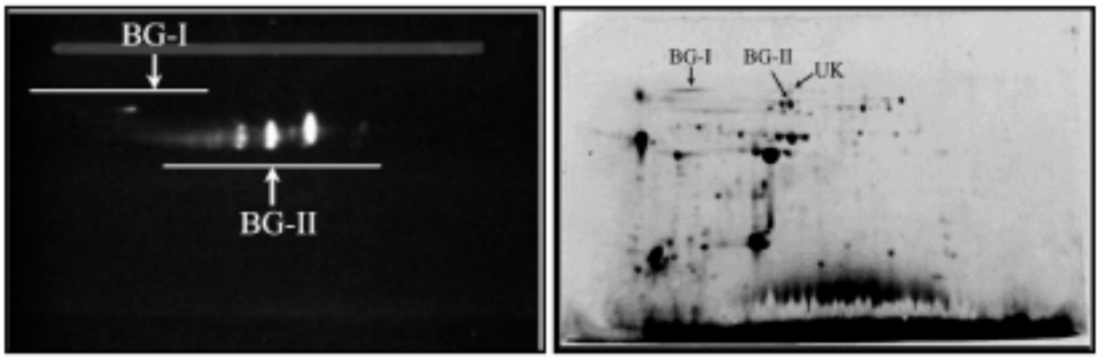
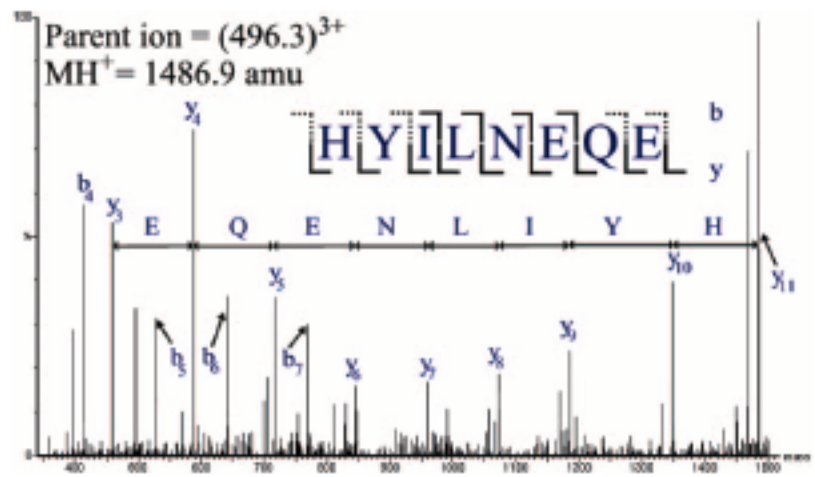


Fig. 2. Imprints and soil profiles from root windows in interior Douglas-fir stands near Barriere, British Columbia, Canada. (a) phosphatase imprint; (b) aminopeptidase imprint, (c) soil image overlain with the same imprint, (d) image of soil profile; (f) β-glucosidase imprint and (e)associated soil image; (h) chitinase imprint and (g) associated soil image. All images are at the same scale.

Dong et al. SBB. 2007.

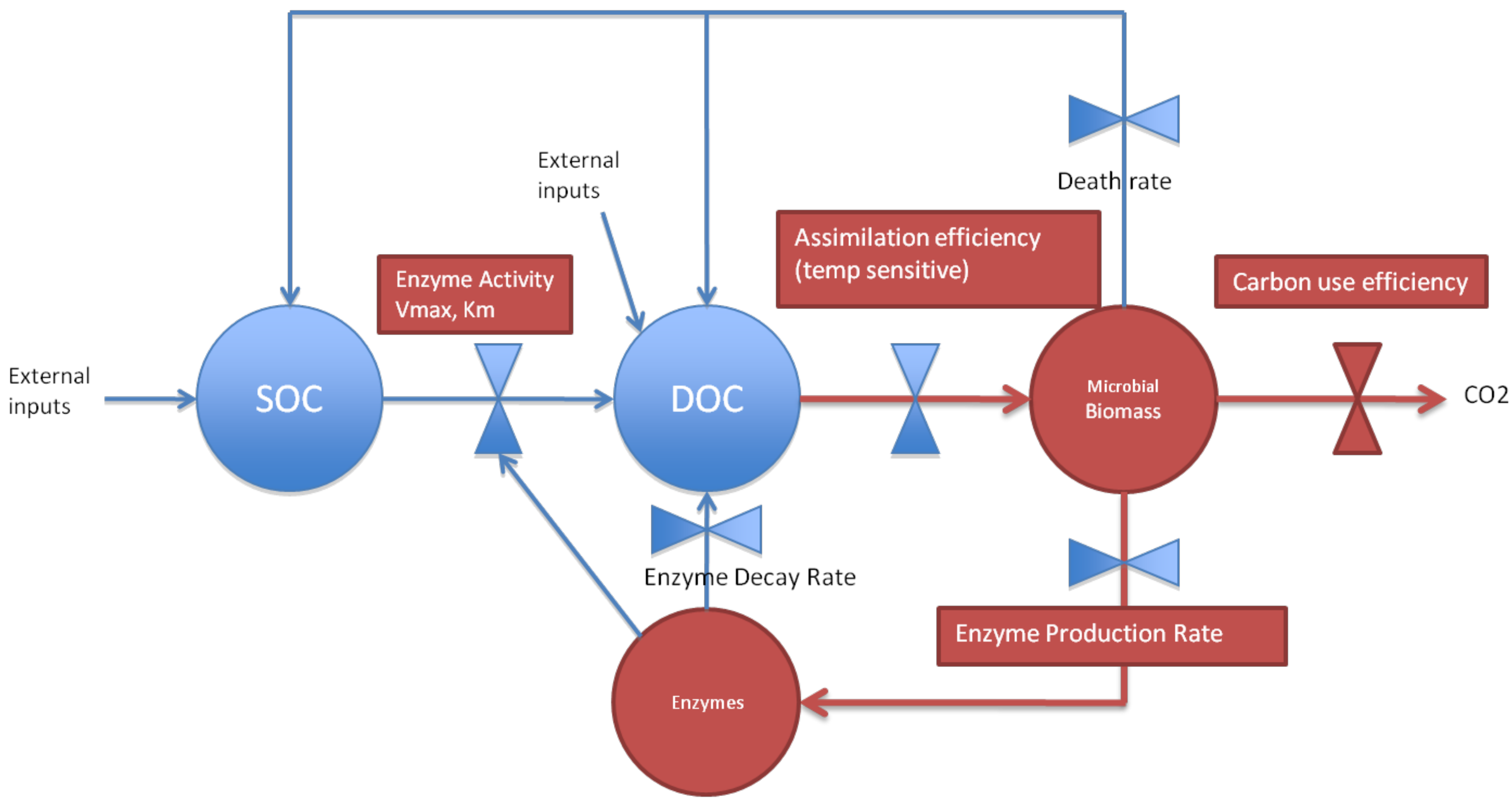
Proteomics





Kim, K.-H., Brown, K. M., Harris, P. V., Langston, J. A., Cherry, J. R., 2007. A Proteomics Strategy To Discover B-Glucosidases from Aspergillus fumigatus with Two-Dimensional Page In-Gel Activity Assay and Tandem Mass Spectrometry. J. Proteome Res. 6, 4749-4757.

Enzyme-explicit models



Allison, S., M. Wallenstein, M. Bradford, submitted

Conclusions

- A convergence of inquisitive questions and novel approaches – let's test our assumptions!
- Towards an integrated understanding of abiotic drivers of biological responses, interactions of enzymes with the soil environment, and substrate-enzyme interactions.
- As we improve our quantitative understanding of soil enzymology, they will become more prominent in the conceptual view of soil biogeochemistry.

Finally, a plug…

The Enzymes in the Environment

Research Coordination Network

http://enzymes.nrel.colostate.edu

Visit our poster on Wednesday!