# Added precipitation and nutrients have different effects on soil microbial enzyme activities across a habitat productivity gradient

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## Background

- There is great need to predict how environmental change will impact ecosystem services on which human well-being depends.
- We must predict ***across landscapes*** that are typically larger and more heterogeneous than the experimental areas on which it is feasible to simulate environmental change.
- Plot-scale experiments ***replicated across site conditions found on the landscape*** can indicate how and how much impacts of environmental change may vary across the larger area, ultimately suggesting the number and distribution of plot-scale studies needed for effective landscape-scale prediction.
- Replicating experiments ***across gradients of a single environmental factor at a time*** (with others held constant) provides greatest power for inference and extrapolation.

**We replicated an environmental change experiment across a gradient of grassland habitat productivity, underlain by three very different soil types in close proximity** (Fig. 1). Climate, vegetation type, and regional species pool remain constant across the gradient.


**Fig 1. Proximity of grassland habitats at the field site.** Harsh serpentine has low N, low Ca:Mg, low water-holding capacity, and low productivity. Lush serpentine and Non-serpentine have higher productivity, but lush serpentine has lower Ca:Mg and higher pH than non-serpentine.

## Methods

Starting in spring 2010, two types of environmental changes have been applied to 2m x 2m plots in a factorial design:

- Late-season precipitation addition (*simulating predicted climate change*)
- NPK nutrient addition

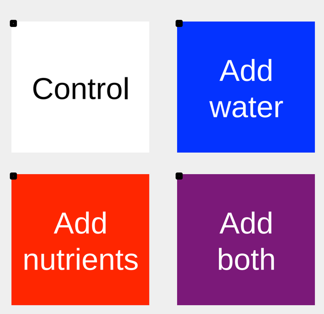


**Fig 2A.** Treatments

This plot series is replicated across the three grassland habitats:

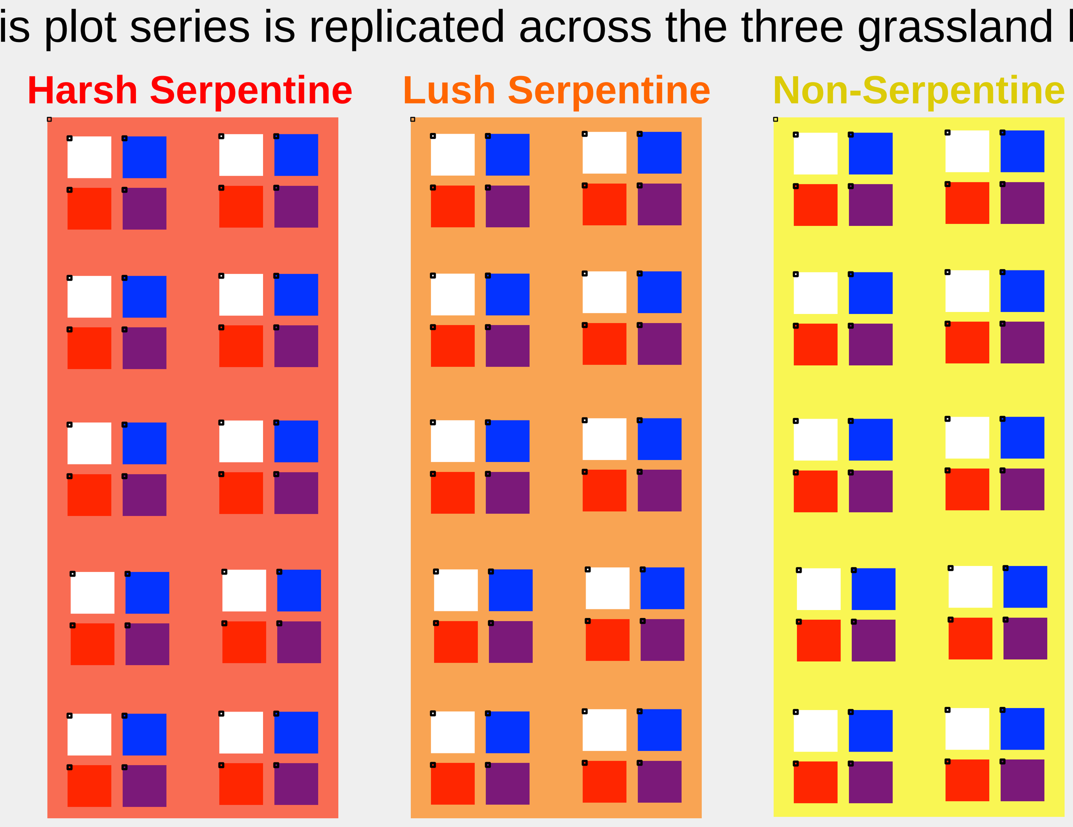


**Fig 2B.** Full experimental design: factorial treatments replicated across habitats

In spring 2013, we measured potential activity of five soil enzymes: β-glucosidase (BG), β-N-acetylglucosaminidase (NAG), acid phosphatase (AP), polyphenol oxidase (PPO), and peroxidase (PER), using fluorometric and colorimetic assays. "Potential activity" refers to reaction with saturating substrate for a standard time period.

## Results


**Fig. 3A-C**. Plots at the time of enzyme sampling (spring 2013). The watering and nutrient treatments largely had additive effects on enzyme activity, with little evidence for a water x nutrient interaction.

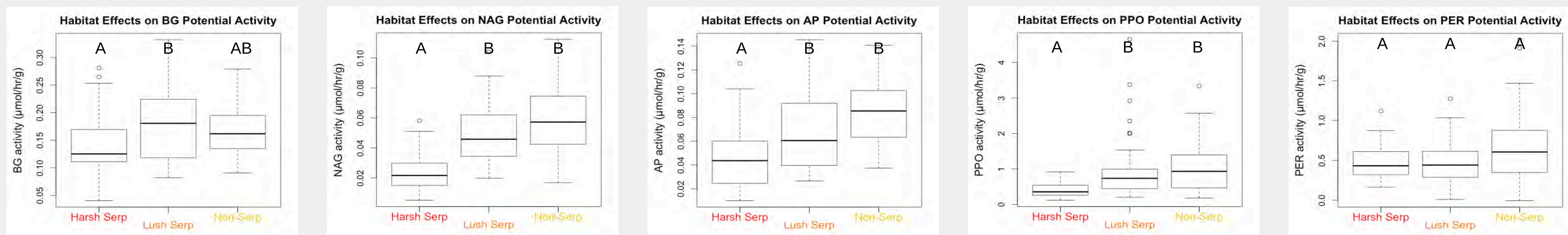


**Fig 4A-E**. Activities of all enzymes except peroxidase (PER) varied by habitat.

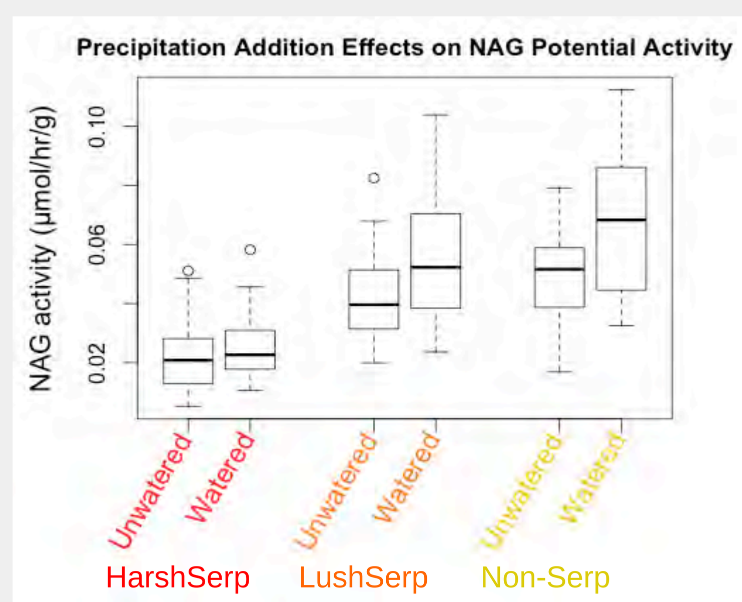


**Fig 5.** Example of how precipitation impacts varied by habitat.

**For most enzymes, the degree to which precipitation addition increased activity varied by habitat**

- Significant or marginally significant habitat x precipitation interaction for 4 of 5 enzymes (e.g., NAG, Figure 5).
- 5th enzyme (PER) showed consistent significant increase across habitats.
- **Precipitation addition significantly increased activity of:**
  - Most enzymes on Non-serpentine
  - Some enzymes on Lush serpentine
  - No enzymes on Harsh serpentine (possibly due to its low water holding capacity)

**Unlike precipitation, nutrient addition impacts did not vary by habitat**

- For BG and NAG (hydrolytic enzymes), nutrient addition increased activity consistently across habitats.
- For AP and the oxidative enzymes PPO and PER, nutrient addition did not increase activity in any habitat.
- Other studies have also found nutrient addition to increase activity of hydrolytic C-harvesting enzymes but not of oxidative C-harvesting enzymes.

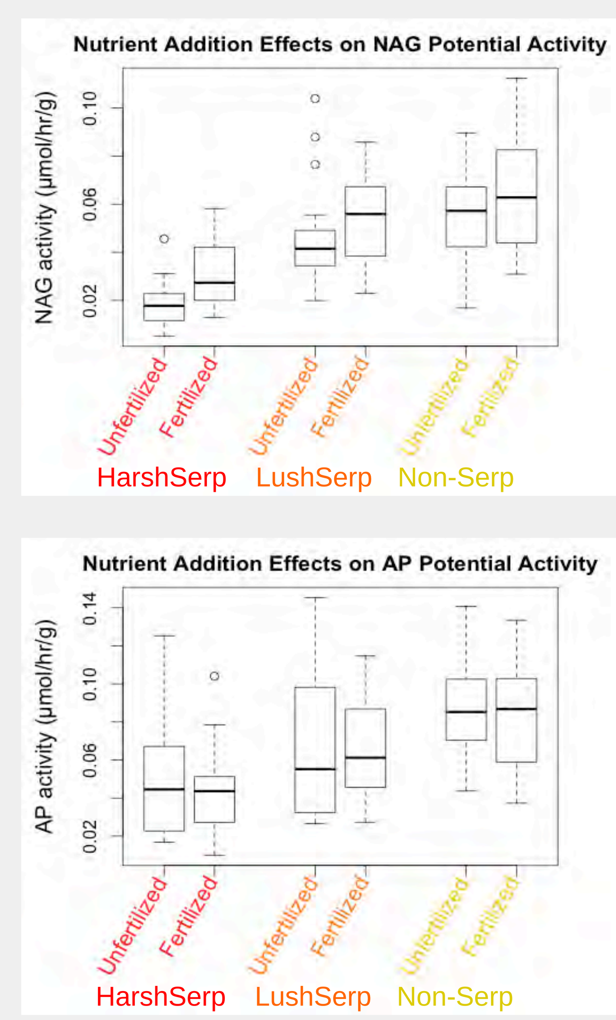


**Fig 6A-B.** Example of how nutrient addition consistently increased activity across habitats for some enzymes but did not affect activity of other enzymes.

## Conclusions

- Nearly all enzyme activities varied among habitats.
- Impacts of precipitation addition were largely habitat-dependent, whereas impacts of nutrient addition were not.
- Precipitation addition affected most enzymes similarly (increased activity on non-serpentine and sometimes on lush serpentine), while nutrient addition increased activity for only some enzymes.
- The environmental changes had additive effects.
- Frequency of habitat-dependence in our results suggests that habitat type *does* need to be considered when predicting across this landscape.

## Future Research

- Measure additional ecosystem services (proteolytic capacity, N mineralization & nitrification) to understand broader suite.
- Measure microbial composition and abundance to suggest which of these (or both) may be driving changes in services.
- Integrate all of these data with measurements of plant community to understand impacts of environmental changes on plant-soil system.

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