Drought stress affects asymbiotic nitrogen fixation in Pacific Northwest prairies

Barbara Bomfim[1], Lucas Silva[1], Scott Bridgham[1], and Brendan Bohannan[1]

[1]University of Oregon

November 22, 2022

Abstract

Background/Question/Methods This project attempts to quantify the resilience of prairie ecosystems to climate change in the Pacific Northwest (PNW). In this region, prairie ecosystems currently sustain ˜1.3 million beef cows and calf production costs are expected to increase to offset drought-induced plant productivity loss. Here, we investigate patterns of asymbiotic nitrogen fixation (ANF) and biogeochemical controls, that also influence plant community composition and prairie productivity, under experimental drought to address a major challenge for sustainable agriculture in the region. We hypothesize that the effect of drought on prairie vegetation cover increases soil asymbiotic N inputs by diminishing the dominance of symbiotic root-fungal networks. To test this hypothesis, we quantified the impacts of decadal drought stress on soil ANF using 15N-labeled dinitrogen (15N2) incubations of soils from high- and low-diversity prairies across a 520-km latitudinal gradient (i.e., southern Oregon-SOR, central Oregon-COR, and central Washington-CWA) representing increasingly severe Mediterranean conditions. We also quantified total soil organic carbon-C, total, and available N, and available phosphorus-P and iron-Fe pools to better understand underlying mechanisms governing drought-induced changes in ANF. At each site, composite soil samples (n = 3) were collected from five co-located high- and low-diversity prairie plots under control (ambient) and drought (-40% precipitation) conditions. Results/Conclusions We found that soil ANF response to drought increased with the PNW Mediterranean drought intensity gradient; while ANF rates increased nearly two-fold in the southernmost site (SOR), a significant decrease in ANF was verified in the northernmost site (CWA). ANF response to drought also varied depending on plant diversity, where low-diversity prairies had a more predictable response to drought than high-diversity prairies. For instance, ANF in SOR high-diversity prairies was suppressed but no change was verified in COR high diversity prairies. Soil C and N contents were generally higher in high-diversity prairies whereas treatment had no significant effect across sites. Soil P availability, also affected by drought, and pH were the most important variables explaining ANF variability across vegetation types and sites. Based on our findings, low-diversity prairies in central WA may be those most severely impacted by increased climate change-induced drought stress. Our study highlights the importance of using soil-plant-atmosphere interactions to assess prairie ecosystem resilience to drought in the PNW.

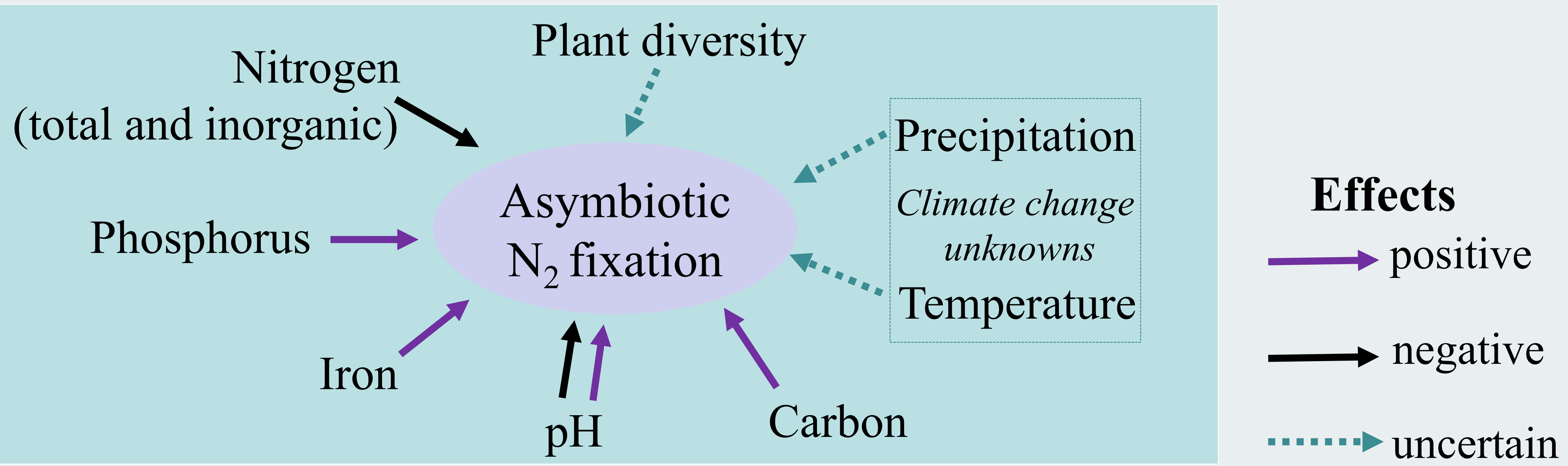
Constrasting seasonal drought stress responses of asymbiotic nitrogen fixation in prairie ecosystems

Barbara Bomfim*, Brendan J.M. Bohannan, Scott D. Bridgham and Lucas C. R. Silva
Institute of Ecology and Evolution, University of Oregon, Eugene, OR ; *presenting author

- Asymbiotic nitrogen fixation (ANF) drought stress response in high- and low-diversity prairies along the U.S. Pacific Northwest varied seasonally.
- ANF in high-diversity prairies of southern Oregon had consistent negative response to drought (−40% precipitation) in Fall and Spring seasons.
- Half of ANF variability was explained by phosphorus and iron availability in soils under ambient conditions but not under drought stress.

Motivation/Research questions

We are investigating patterns of asymbiotic nitrogen fixation (ANF) and its biogeochemical controls, which may influence plant community composition and prairie productivity, under experimental drought (−40% precipitation) to address a major challenge for sustainable agriculture in the U.S. Pacific Northwest region.



i) Does soil ANF respond to drought stress in prairie ecosystems along the U.S. Mediterranean drought severity gradient? If so, does the response differ between low- and high-diversity prairies and seasons?

ii) Do biogeochemical controls on ANF respond to drought stress along drought severity gradient?

Methods

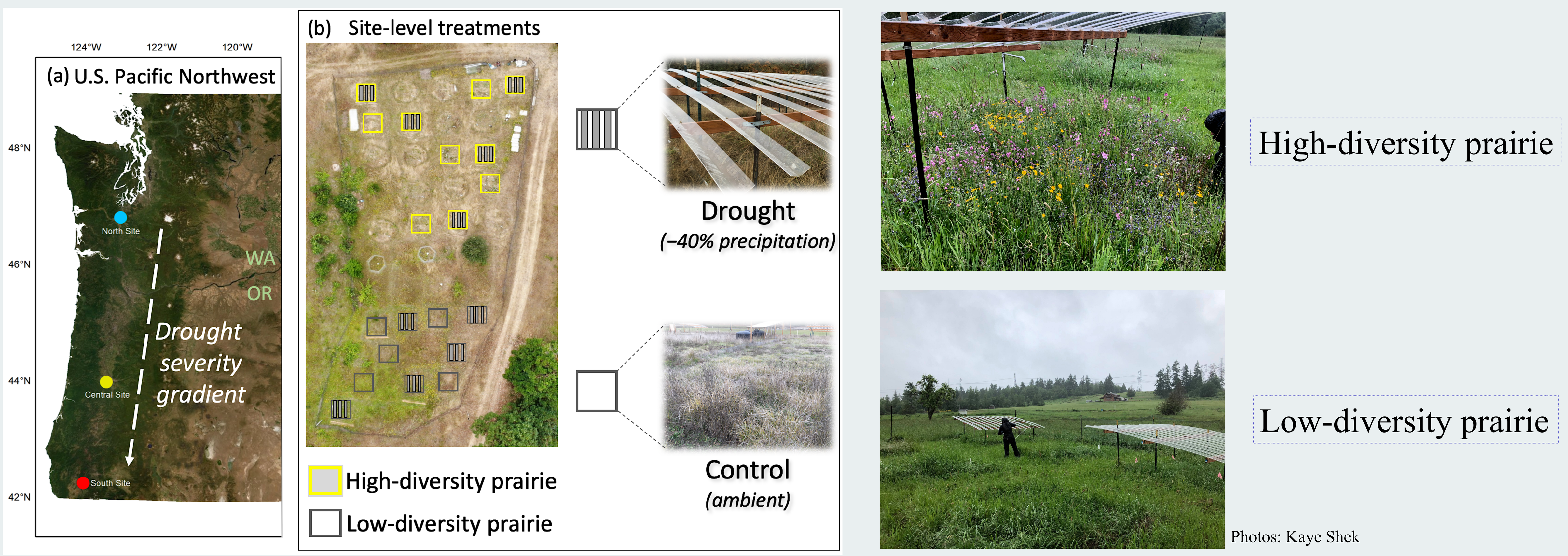


Figure 1. Study region map and the three study sites representing the U.S. Pacific Northwest drought severity gradient. At each site, composite soil samples (n = 3) were collected in the fall and spring seasons from five co-located high- and low-diversity prairie plots under control (ambient) and drought (−40% precipitation) conditions.

soil sample (0-10 cm)

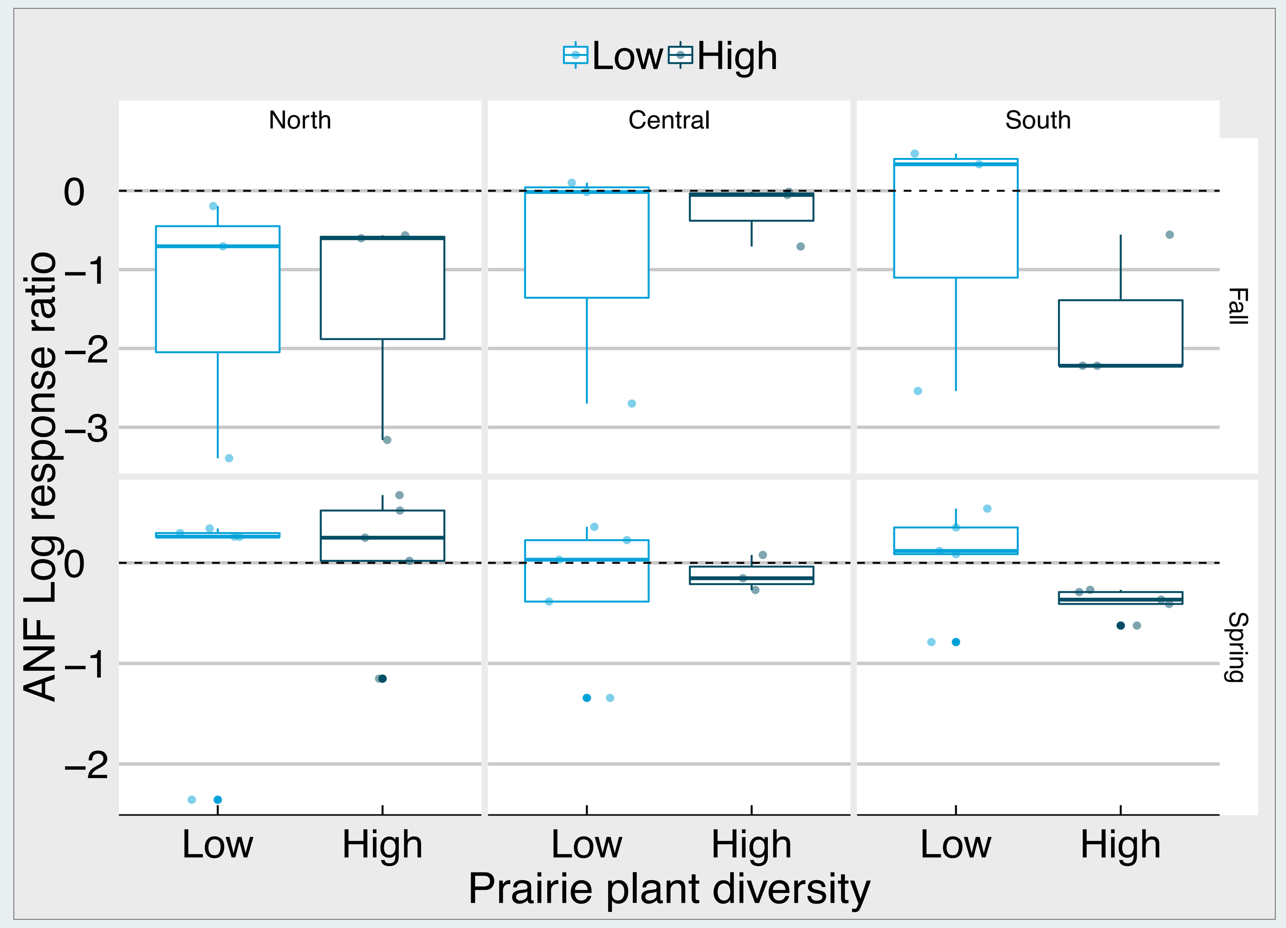
Incubation with $^{15}N_2$ (24 hours at 25°C) → Oven-drying, grinding and encapsulating → UC Davis Stable Isotope Facility → ^{15}N atom-% → **ANF rate ng N g^{-1} h^{-1}**

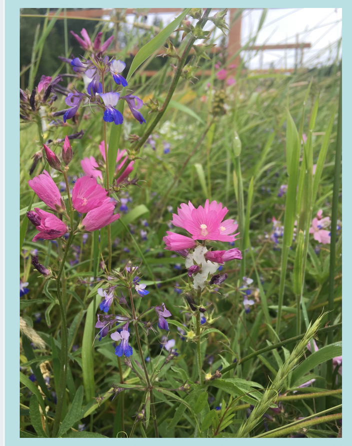
Oven-drying (48 hours at 100°C) → Sieving (2 mm) → Biogeochemical controls

KCl extractions: **NH_4^+ and NO_2^- + NO_3^-**
Mehlich-3 available **P** and **Fe**
Total N and C
pH H_2O and $CaCl_2$

Results

i) ANF drought stress response varies seasonally

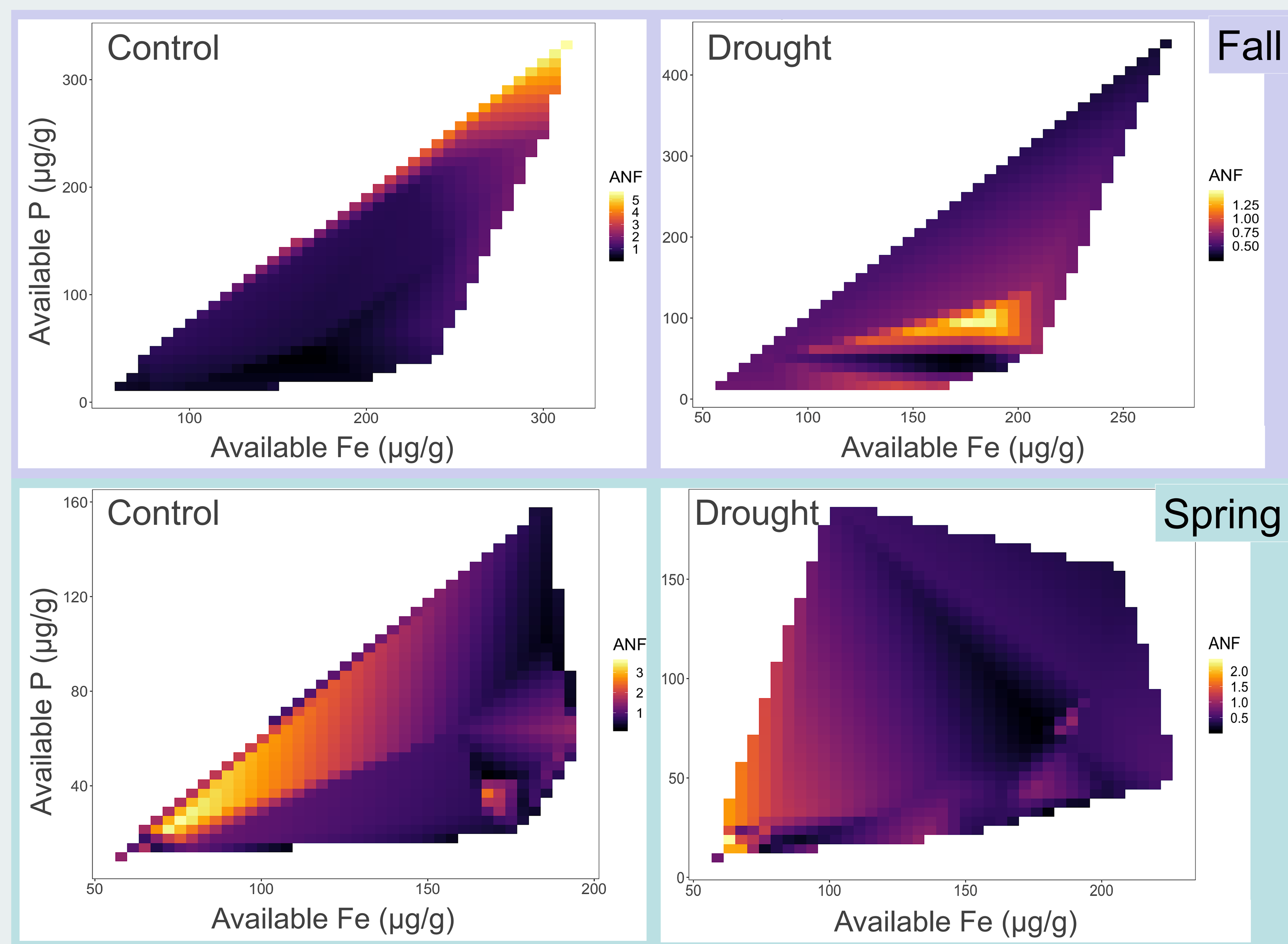




Consistent negative drought response of soil ANF in high-diversity prairies in southern Oregon in the fall and spring seasons.

Figure 2. Log response ratio [$\log_{10}$(ANF drought / ANF control)] of soil ANF in samples collected in the three study sites along the PNW drought severity gradient.

ii) Biogeochemical controls on ANF are seasonally affected by drought



Available Fe and P, interacting with treatment, significantly explained 50% of ANF in control (p<.001) but not in drought soils (p>.1). Generalized additive model, R^2_{adj} = 0.44, variance explained = 50%.

Figure 3. Interpolation of ANF rate (ng N g dry weight^{-1} h^{-1}) as a function of available iron (Fe, x axes) and available phosphorus (P, y axes) in control and drought praire soils sampled in the fall and spring seasons.

Acknowledgements

This work was financially supported by NSF (PBI) 1758947 and the first author is a NEON-ESA Early Career Scholar 2019. The authors thank all members of the Soil Plant Atmosphere Research Lab for support throughout this project, especially Toby Maxwell, Hilary Dawson and Shae Davis for laboratory assistance, and Weicheng Wang for study region map preparation. Special thanks to Hallett Lab (Ashley Shaw), McGuire Lab (Kaye Shek), Bridgham Lab (Aaron Nelson, Graham Bailes, Paul Reed, Laurel Pfeifer-Meister), Bart Johnson, Bohannan Lab and the Institute of Ecology and Evolution at the University of Oregon, Eugene.