Seasonal Effects of Experimental Warming on Soil Biogeochemistry and Plant Functional Diversity in Pacific Northwest Prairies

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Abstract

This project aims to quantify the resiliency of prairie ecosystems in the U.S. Pacific Northwest (PNW) to climate change. Prairies in this region sustain over one million beef cows, and cow-calf production costs are expected to increase to offset warming-induced plant productivity loss. We investigated the above- and belowground effects of experimental warming in prairie ecosystems by assessing biogeochemical controls on and patterns of asymbiotic nitrogen fixation (ANF), plant species diversity, and legume cover to address a major challenge for sustainable agriculture in the region. We hypothesize that the effect of warming on prairie functional diversity increases soil asymbiotic nitrogen inputs by decreasing legume cover and soil nitrogen availability. We quantified the effects of decadal warming stress (+2.5ºC) on soil biogeochemical properties and plant species and functional diversity during fall and spring seasons in three sites along a 520km latitudinal gradient—from central Washington to southern Oregon—representing a drought severity gradient. At each site, we collected composite soil samples from five co-located prairie plots under control (ambient) and warming conditions. We incubated these soils using 15N-labeled dinitrogen (15N2), and quantified total soil carbon, total and available nitrogen, and available phosphorus and iron pools to better understand the underlying mechanisms governing warming-induced changes in ANF. We used a point intercept technique to survey plot-level plant community composition and calculate Shannon's diversity index and percent cover of legumes (members of Fabaceae according to the Integrated Taxonomic Information System). Warming significantly decreased plant species diversity which also decreased along the drought severity gradient. Legume cover significantly increased from 3.1% in the north to 9.2% in the south. ANF response to warming varied by season and site, where rates increased with the drought severity gradient in the fall but decreased during the spring. Total soil inorganic nitrogen availability was the strongest predictor of ANF response to warming in the spring but not in the fall. Our study highlights the importance of using soil-plant-atmosphere interactions to assess prairie ecosystem resilience to climate change in the PNW.

Seasonal Effects of Experimental Warming on Soil Asymbiotic N_2 fixation and Plant Functional Diversity in Pacific Northwest Prairies

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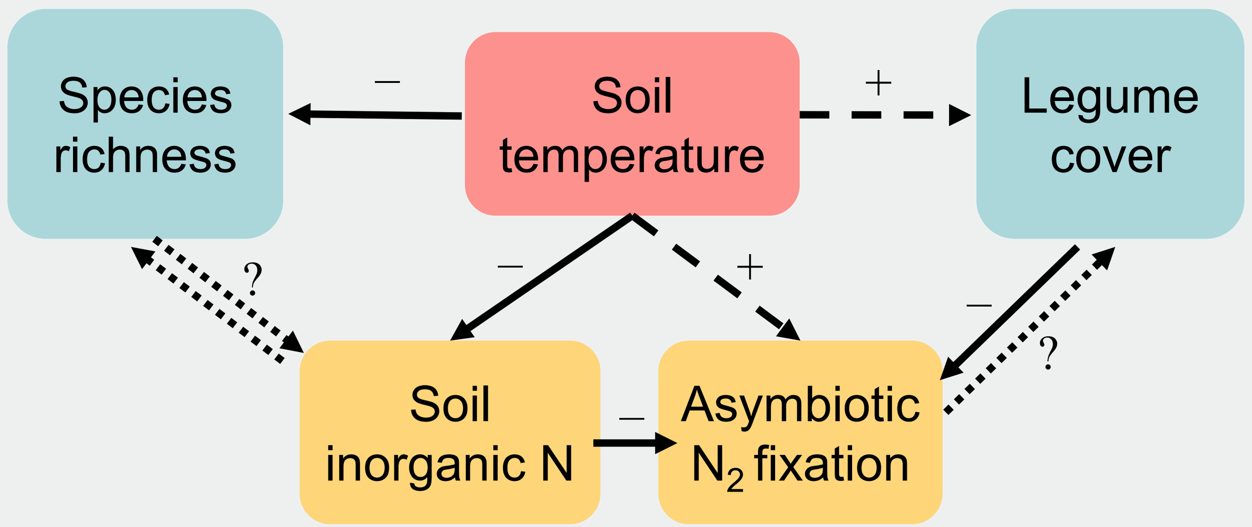
- Warming (+ 2.5–3.0ºC) effect on soil asymbiotic N_2 fixation in Fall and Spring varied across a climate gradient of Pacific Northwest prairies.
- Soil inorganic nitrogen pools were minimally affected by warming in all sites, except for Fall nitrate pool in the Northern site.
- Warming had positive effect on prairie legume cover but the magnitude of change varied across the climate gradient.

Motivation and Research Questions

This project aims to quantify the resiliency of U.S. Pacific Northwest (PNW) prairies, which are critically endangered ecosystems, to climate change. We quantified the effect of warming (+ 2.5–3.0ºC) on soil asymbiotic N_2 fixation (ANF) and major biogeochemical controls in Fall and Spring across a climate gradient of PNW prairies, and related those with plant species richness and functional diversity.

i) Does warming affect plant species richness and legume cover in prairies along the U.S. Mediterranean drought severity gradient?
ii) Does warming affect soil ANF? If so, does the effect vary among Fall and Spring seasons?
iii) Do biogeochemical controls (i.e. soil inorganic N pools) on ANF respond to warming?



Study Sites and Experimental Design

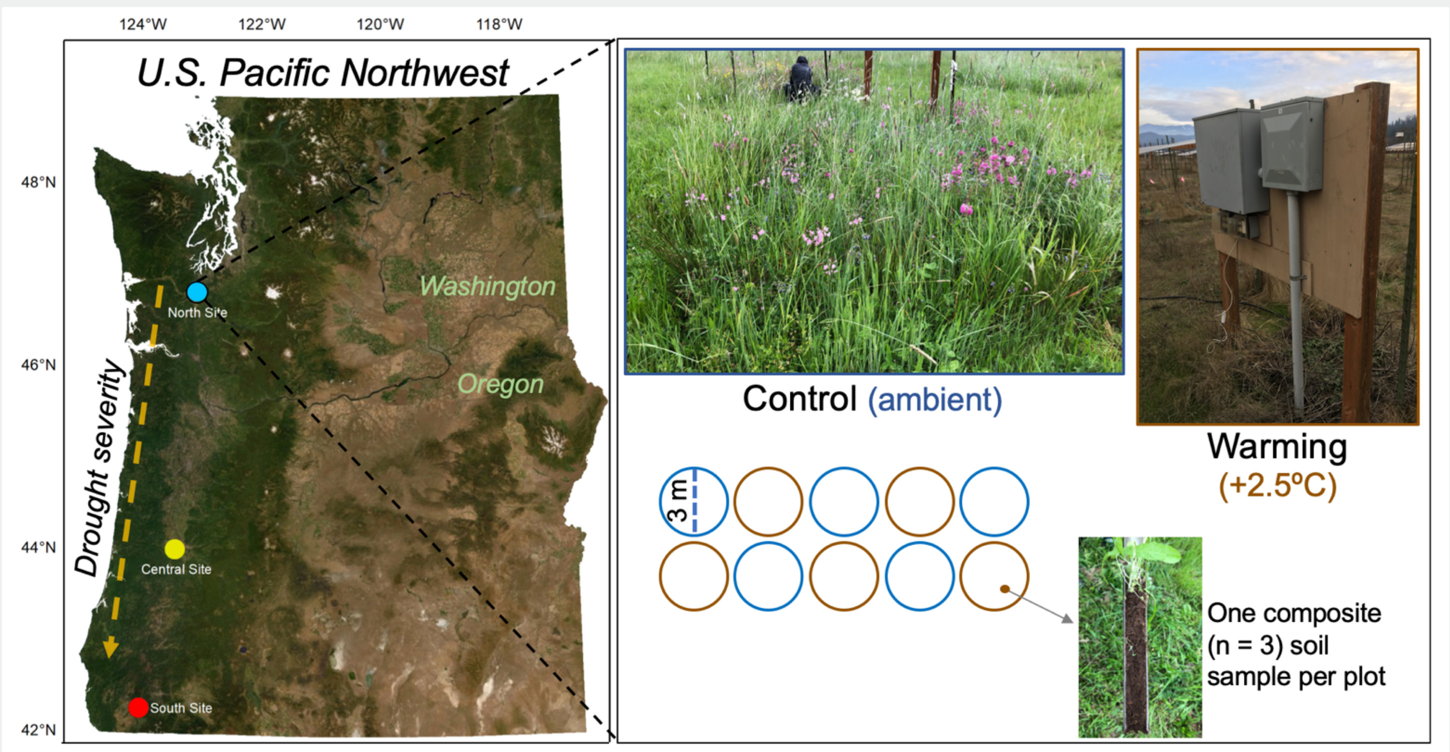


Fig. 1 Location of study sites (North, Central, South) along the U.S. Mediterranean drought severity gradient. At each site, composite soil samples were collected in Fall and Spring seasons from five prairie plots under warming (six 2000-watt infrared heaters designed to heat the canopy by + 2.5–3.0ºC) and five under control (ambient temperature with 'dummy heaters' to mitigate any shading effect the heaters may produce) conditions.

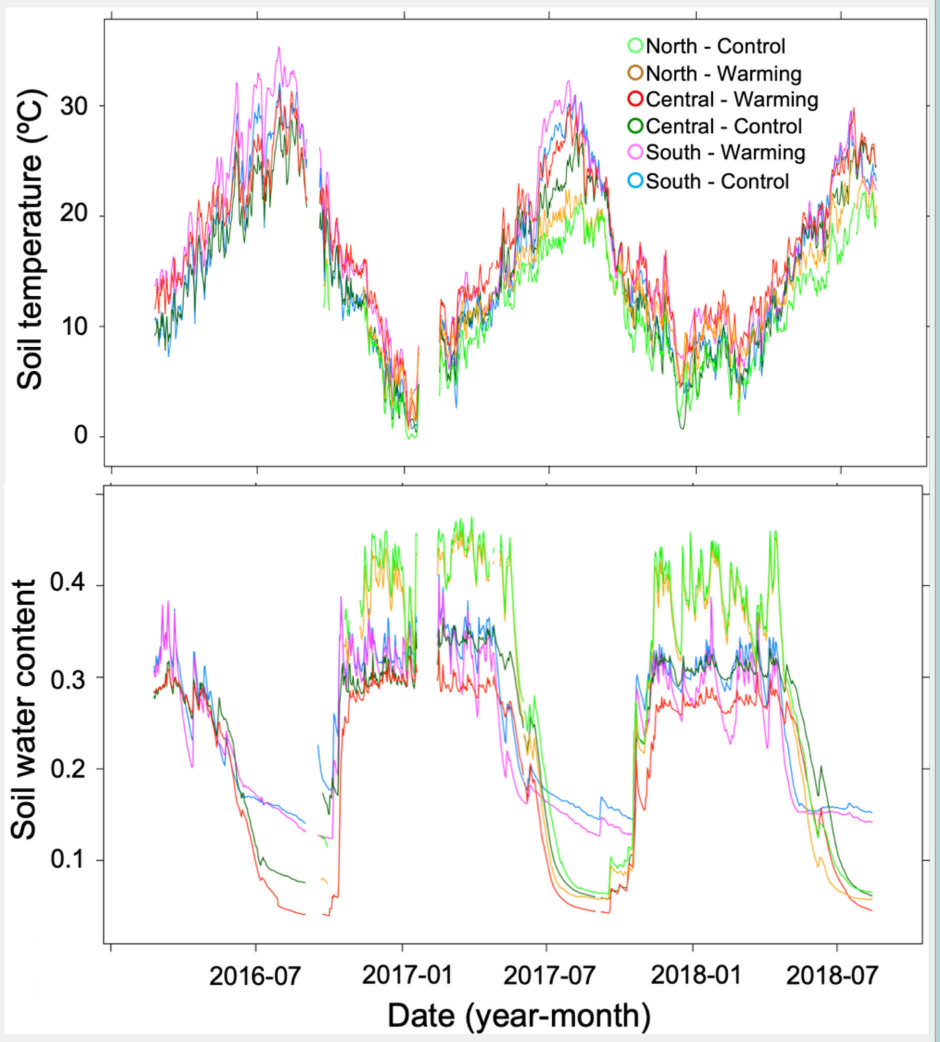


Fig. 2 Daily average soil temperature and water content in control and warming plots across sites between Jan-2016 and Aug-2018.

Laboratory workflow

Soil sample (0–10 cm)

- Incubation with $^{15}N_2$ (24 hours at 25ºC) → 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 100ºC) → Sieving (2 mm) → **Biogeochemical controls**
  - KCl extractions: **NH_4^+ and NO_3^-**
  - Mehlich-3 available P and Fe
  - Total N and C
  - pH H_2O and $CaCl_2$

Not presented here

Results

i) Warming effects on species richness and legume cover varied across the gradient

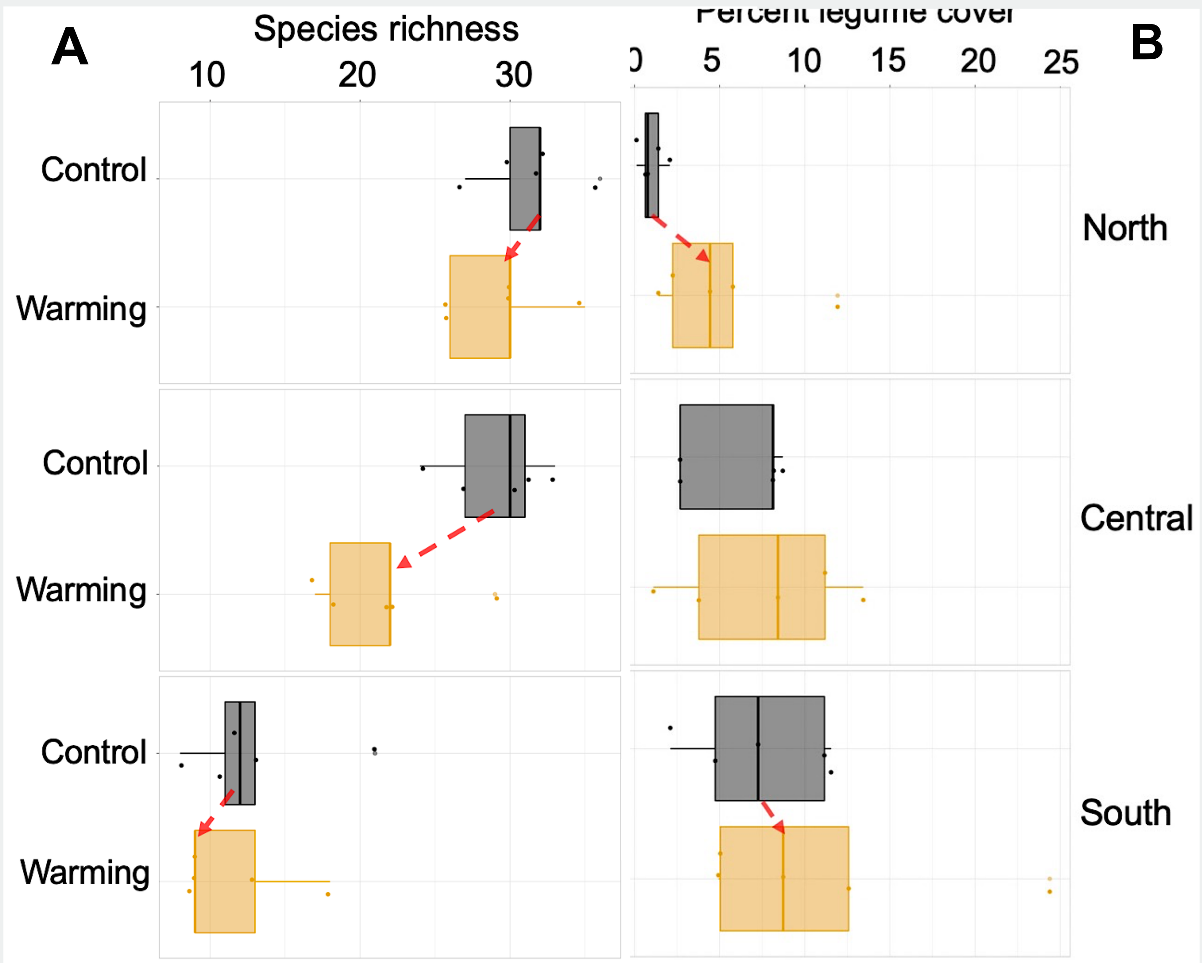


Fig. 3 (A) Species richness and **(B)** percent legume cover (members of the Fabaceae family) in control and warming plots in each study site. Measurement of plant cover by species using the point intercept method was done in Spring 2018 (Pfeifer-Meister et al. 2012, 2016).

ii) Warming effect on soil ANF varied by site and season

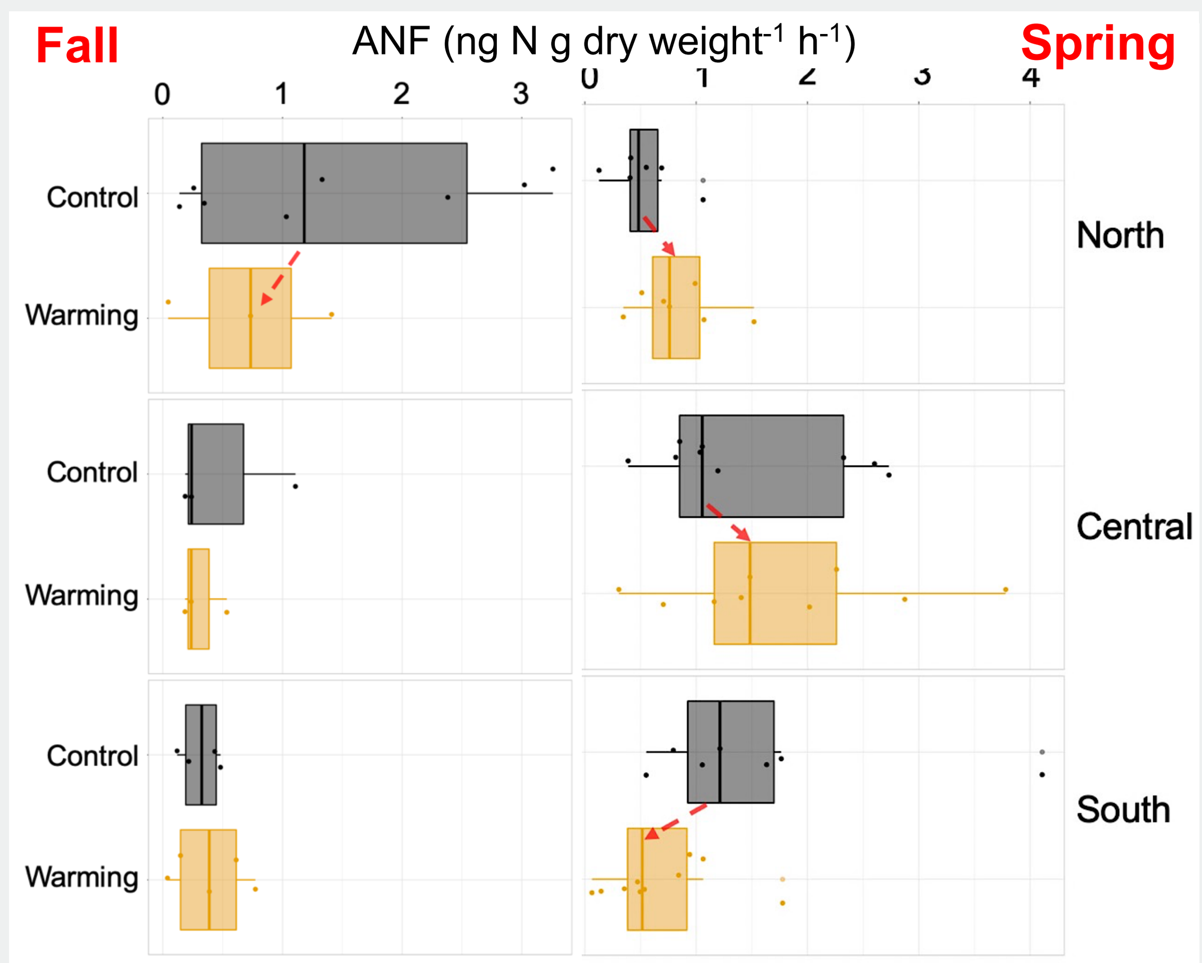


Fig. 4 Mean ANF rates of soils under control and warming conditions in sites representing a climate gradient of Mediterranean prairies. Sampling done in Fall 2018 (Nov/Dec) and Spring 2019 (April/May).

iii) Warming had small effect on soil ammonium and nitrate in both seasons

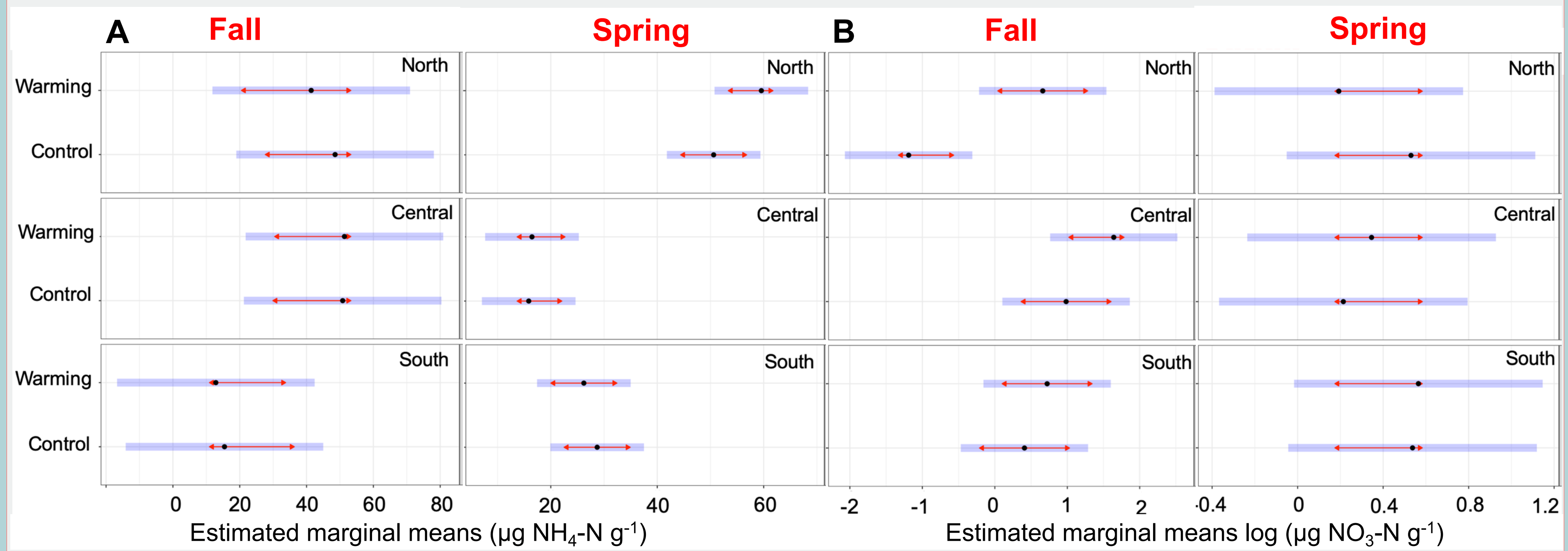


Fig. 5 Comparisons of soil ammonium (**A**) and nitrate (**B**) means in control and warming treatments in Fall and Spring.

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