Soil microbial community response to climate change: Results from a temperate Kentucky pasture

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Introduction:

Climate change is likely to alter plant-soil interactions that govern nutrient dynamics and thereby dictate the quantity and quality of food crops and forage produced on agricultural lands.

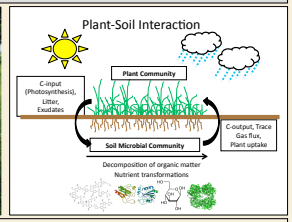
Soil microorganisms mediate decomposition of organic matter and nutrient availability for plants, and are influenced by climate change factors such as temperature and moisture regimes. However, understanding how soil microbial communities will respond to climate change is often complicated by the fact that these organisms are also sensitive to seasonal changes in temperature, water availability, and plant community composition and activity. Therefore, soil microbial responses to climate change may vary depending on the season in which the responses are measured.

Objective:

❖To quantify seasonal responses of soil microbes to the climate change factors of increased temperature (+3ºC) and precipitation (+30% of the long-term mean annual).

Hypotheses:

❖ Seasonal variability will be observed in microbial activity and community composition.
❖The effects of added heat and precipitation on microbial community composition and activity will be additive.
❖ Warming and increased precipitation will produce more dramatic effects on microbes in the season where these factors are most limiting, e.g., winter and spring for added heat treatment; summer for added precipitation.



Study Site:

A hay-managed temperate grassland in Lexington, Kentucky, that contains 20, three meter diameter plots, five replicates of four climate treatments.

1. Heated (+3°C day and night, year-round), **+Heat**
2. Precipitation increase (+30% of long-term mean annual applied during the growing season), **+Precip**
3. Heat and Precipitation increase, combined , **+Heat+Precip**
4. Control, untreated/ambient, **Control**

Dominant forage species include: Tall Fescue, Kentucky Bluegrass, Bermudagrass, and Crabgrass

Methods:

Soil Collection Dates: Spring—May 2011; Summer—July 2011; Fall—October 2011; Winter—February 2012

Soil Microbial Community Biomass and Structure
•**Chloroform Fumigation Extraction (CFE)** (Brookes et al., 1985; Scott-Denton et al., 2006)
•**Phospholipid Fatty Acid Analysis (PLFA)** (Findlay and Dobbs, 1993).

Soil Microbial Community Function
•**Extracellular Enzyme Activity** (Saiya-Cork et al., 2002; Weintraub et al., 2007).
•**Carbon Mineralization Assay (CMA)** (Fierer et al., 2003; Iqbal et al., 2012).
•**Catabolic Response Profiles (CRP)** (Degens and Harris, 1997; Degens and Vojovodic, 1999).

Statistical Analysis, SAS 9.3
•Mixed effects linear model procedure (Proc Mixed) with a factorial, repeated measures design
•Main effects = Season, Treatment; Repeated measures = treatment within blocks

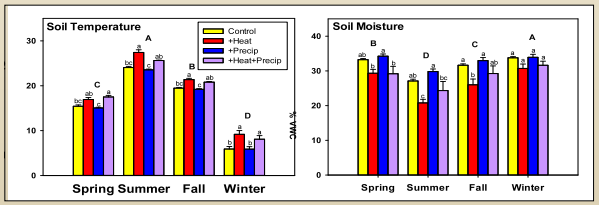
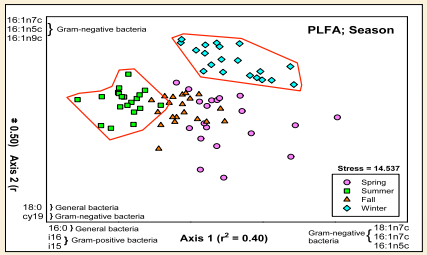


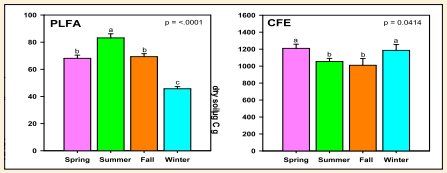
Figure 1: Daily soil temperature (°C) and soil volumetric water content (% VWC) averaged across the month preceding seasonal soil sampling for each treatment. The main effect of season is represented by capital letters ($P < 0.05$), and within a season, the effects of treatment are indicated by small letters ($P < 0.05$).

Seasonal Effects

Microbial Community Composition



Microbial Biomass



(Left) **Figure 2:** Non-metric multidimensional scaling ordination of the 20 most abundant phospholipid biomarkers for all samples collected during this study. (Above) **Figure 3:** Microbial biomass results from Chloroform Fumigation Extraction (CFE) and Phospholipid Fatty Acid Analysis (PLFA) results for the main effect of season.

Enzyme Activity

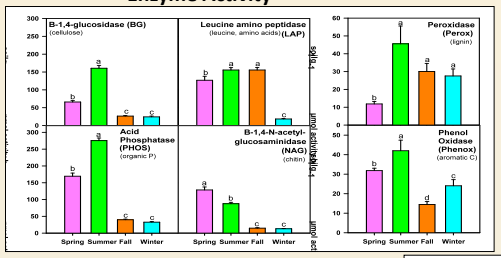


Figure 4 : Extracellular enzyme activities with significant seasonal main effects.

❖ Extracellular enzyme activities were generally highest in either the spring or summer (Figure 4).

❖ Seasonal patterns of substrate induced respiration were dependent on the substrate utilized (Figure 5).

❖ Soil microbial community structure differed between each season, particularly between Summer and Winter soils (Figure 2).

❖ Summer maxima and Winter minima were identified in microbial biomass via total phospholipids (PLFA), although microbial biomass carbon (CFE) was highest in the spring and winter (Figure 3).

Catabolic Response

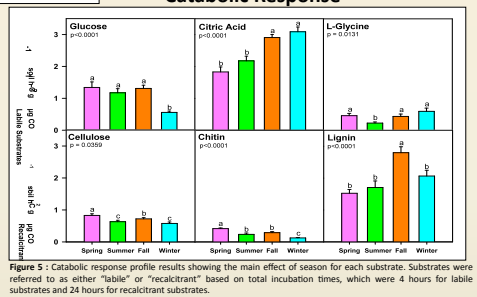


Figure 5 : Catabolic response profile results showing the main effect of season for each substrate. Substrates were referred to as either "labile" or "recalcitrant" based on total incubation times, which were 4 hours for labile substrates and 24 hours for recalcitrant substrates.

Climate Treatment Effects

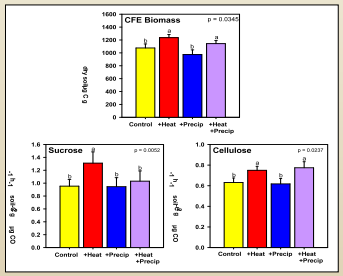


Figure 6: Significant climate treatment effects for microbial biomass from CFE (above), catabolic responses to sucrose addition (lower left) and to cellulose addition (lower right).

❖No additive effects of climate treatments were observed in this study.

❖ +Heat and +Heat+Precip treatments increased microbial biomass and catabolic response to cellulose.

❖ +Heat increased catabolic response to sucrose.

Season X Treatment Effect

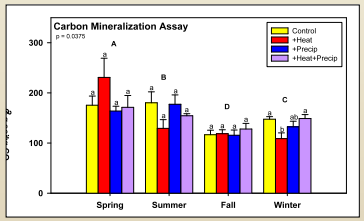
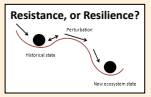


Figure 7: Carbon Mineralization Assay (CMA) results showing the seasonal effects and treatment effects within season. Although a significant treatment x season interaction was found, for ease of interpretation, the main effect of season is represented by capital letters, and within a season, the effect of treatment is indicated by small letters ($P < 0.05$).

❖ A significant season x treatment interaction appeared to be driven by +Heat effect in Winter.

❖Resistance or resilience of the soil microbial community could explain the lack of response to climate treatments in this study.
❖Resistant: More robust responses to increased heat and precipitation may develop over time.
❖Resilient: Resumed normal function after initial perturbation due to climate treatments.



Based on Scheffer, M., and S. R. Carpenter. 2003. Catastrophic regime shifts in ecosystems: linking theory to observation. TRENDS in Ecology and Evolution **18**(12): 648—656.

Conclusions:

❖Strong seasonal variability across all parameters was observed.

❖Surprisingly, few significant main effects of climate treatments were measured, and those that were did not demonstrate additive effects of increased heat and precipitation.

❖Contrary to our hypothesis, the effects of climate treatments largely did not vary by season.

❖The soil microbial community of this temperate Kentucky pasture was influenced more by seasonal variation than by continuous increases in heat and precipitation.

❖This system may not be significantly altered by future changes in climate.

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