Soil Nutrient and Microbial Response to Kentucky Bluegrass Invasion and Land Management Techniques

Leslie Gerhard, Caley Gasch and Kevin Sedivec
Department of Soil Science, North Dakota State University, Fargo, N.D.

The overall objective of this research was to examine below-ground characteristics under accumulated Kentucky bluegrass conditions and in response to management with fire and grazing. We present results from treatments of idle management, resulting in Kentucky bluegrass monocultures, compared with those that were burned in the spring and grazed throughout the growing season.

Kentucky bluegrass monoculture (left) and thatch (right).
Megan Dornbusch, NDSU

Introduction

The fact that invasive species are a contributing factor to the decline of grasslands in the northern Great Plains has been well documented (Cully et al., 2003). Kentucky bluegrass (*Poa pratensis L.*) is one of the main invasive species encroaching on endemic species in these ecosystems. The species has expanded rapidly in the last 30 years (DeKeyser et al., 2009) and is present in 82 percent of most areas of North Dakota (U.S. Department of Agriculture, 2014).

Kentucky bluegrass (hereafter referred to as bluegrass) is an effective competitor and produces abundant litter, which, in turn, creates a thick thatch layer of living and dead plant material between the soil surface and the plant canopy. Dominance of bluegrass, and the resulting accumulation of thatch, has the potential to reduce provisioning ecosystem services and functions (Toledo et al., 2014).

If bluegrass continues to invade remaining grasslands at its current rate, biodiversity will diminish at rates that may not be reversible. Biodiversity is one of the most important factors influencing primary productivity (Tilman et al., 2012), so maintaining species diversity in forage-producing rangelands is particularly important. The pervasiveness of bluegrass is likely to increase if adaptive land management techniques are not adopted.

In the northern Great Plains, patch-burn grazing is being explored as a land management technique. This disturbance-driven management model can help reduce the bluegrass thatch layer and promote the regeneration of native plant species. Seasonal prescribed fire is shown to reduce bluegrass cover up to nearly 30 percent one growing season post-fire (Kral et al., 2018). Additionally, this management model helps promote heterogeneity and diversity across the landscape.

While bluegrass and patch-burn grazing are often thought of as primarily above-ground issues, many below-ground impacts often are overlooked. Research has shown that bluegrass has the potential to disrupt soil nutrient cycling, surface hydrology and structure (Taylor and Blake, 1982; Wedin and Tilman, 1990; Herrick et al., 2001). Depending on the disturbance regime, fire and grazing have varying and interactive impacts on soil nutrient budgets, hydrology and microbial populations (Hobbs et al., 1991; Zhao et al., 2017; Alcañiz et al., 2018).

With these below-ground impacts in mind, we hypothesized that the dominance of bluegrass and development of thatch may lead to a different soil microclimate, as well as organic-matter inputs, that are different in quality and quantity than on land managed with a combination of fire and grazing. These differences in microclimate and organic matter inputs may, in turn, affect soil nutrient and microbial dynamics. Additionally, fire and grazing may have direct impacts on these soil properties.

Methods

This research was conducted at the Central Grasslands Research Extension Center (CGREC) in the mixed-grass prairie typical of central North Dakota. We established replicate sites, distributed across the research center, in pastures that are managed with a patch-burn grazing model. We selected ecologically similar site locations based on soil series descriptions (USDA, 2017a) and ecological site descriptions (USDA, 2017b) to minimize environmental variation.

Our treatments consisted of 12 replicate sites in total. Eight of the sites received moderate season-long grazing and were burned in the spring. These management practices help reduce bluegrass and promote native grass, and forb species expression and/or germination (DeKeyser et al., 2009).

Half of the managed replicate sites were burned in the spring of 2017 (*2017 Mgmt.*), allowing for a year of native vegetation recovery post-disturbance. The other half were burned in the spring of 2018 (*2018 Mgmt.*) to account for immediate and in-season effects of management practices on soil properties.

The remaining four replicate sites were located in exclosures that had not been burned or grazed in recent management history (*Bluegrass*). The extreme idle management resulted in the formation of bluegrass monocultures and the accumulation of a thick thatch layer.

Composite soil samples were collected from each treatment across all replicates at the beginning of the 2018 growing season. We divided soil samples into depths of 0 to 5 centimeters (cm) and 5 to 15 cm for analysis of surface and near-surface soil conditions.

To understand direct impacts of fire and grazing on soil properties, we collected subsequent soil samples from the sites burned in the spring of 2018 throughout the growing season. We sampled these sites immediately following the 2018 spring fire event, and then at time steps of one month and three months post-fire.

The soil was analyzed for labile and stable fractions of carbon and nitrogen pools, and for microbial abundance and community structure.

Soil carbon pools were analyzed for total carbon, organic carbon and permanganate oxidizable carbon (POX C). POX C represents the most labile fraction of carbon, which is readily accessible to microbial populations, and was expected to be the fraction most sensitive to shifts in vegetation structure and management practices (Culman et al., 2012).

Soil nitrogen pools were analyzed for total nitrogen, ammonium (NH4-N), nitrate (NO3-N) and potentially mineralizable nitrogen (PMN). Ammonium and nitrates are forms of nitrogen easily taken up by plants, while PMN is an indicator of the nitrogen mineralization capacity of the microbial community (Cornell University, 2017).

Lastly, we analyzed soil microbial population abundance and community structure. Microbial biomass carbon (MBC) is an indicator of the carbon abundance within the cells of living soil organisms (Vance et al., 1987). Relative microbial community structure was determined using phospholipid-derived fatty acid (PLFA) analysis. The PLFA method estimates microbial groups at a broad taxonomic level, and it is an effective method for detecting shifts in microbial communities across treatments (Ramsey et al., 2006).

We analyzed differences among treatments using the Kruskall-Wallis test with Wilcoxon pairwise post-hoc tests used for mean comparisons. Significant differences were determined at a $p \leq 0.05$.

Results

Soil carbon, nitrogen and microbial population analyses are detailed in Figures 1-3, respectively. Predictably, no differences were detected in the more stable fractions of either nutrient pool. We did, however, detect differences in the most highly dynamic and labile fractions of the soil carbon and nitrogen pools.

POX C and NH4-N showed differences in both sampled depths. However, based on the timing of the detected changes throughout the season, determining with certainty that treatment differences were the cause is difficult.

Excluding the 5 to 15 cm depth for POX C, no differences were detected between *Bluegrass*, *2017 mgmt.* and *2018 mgmt.* pre-fire samples. This suggests that the changes observed subsequently throughout the growing season were likely a result of abiotic environmental fluctuations in soil moisture and temperature. Microbial community distributions showed no differences across treatments or throughout the season.

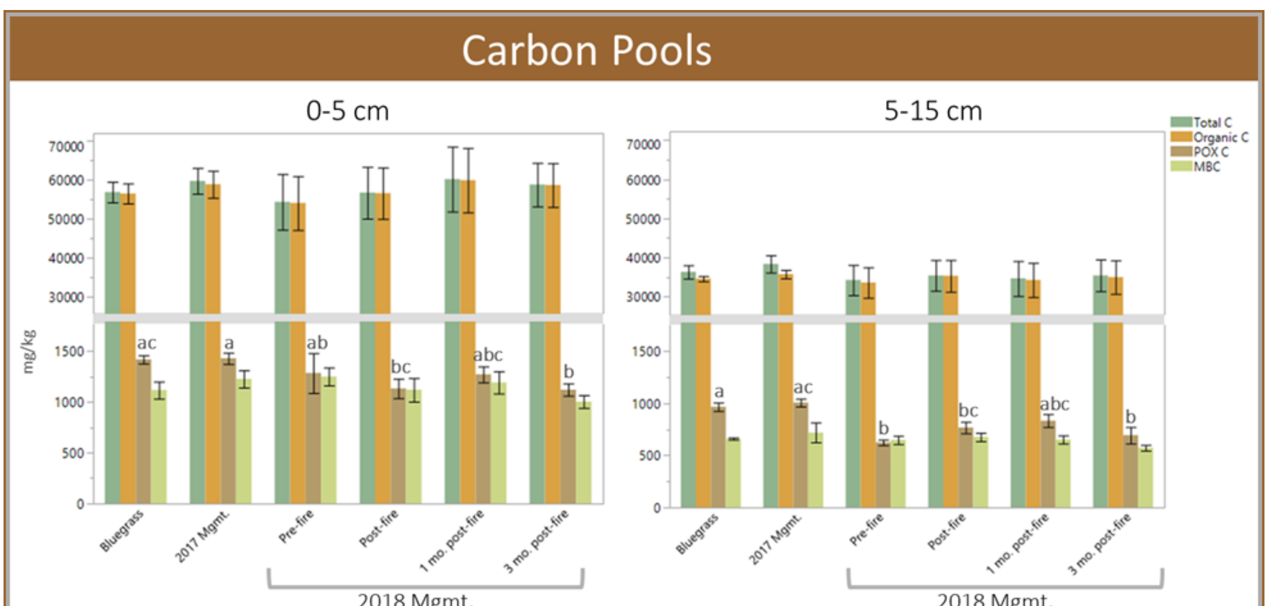

Fig. 1 Effect of management on mean soil carbon fractions (n=4 for each property measured). Different letters indicate significant differences across treatments, within a depth.

Nitrogen Pools

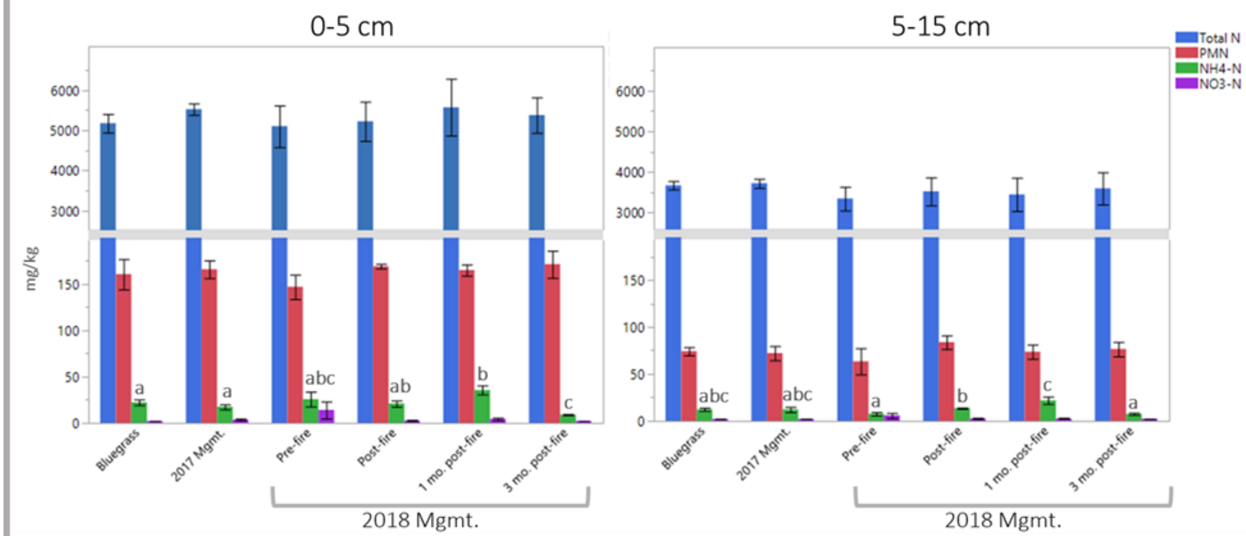

Fig. 2 Effect of management on mean soil nitrogen fractions (n=4 for each property measured). Different letters indicate significant differences across treatments, within a depth.

Microbial Community Structure

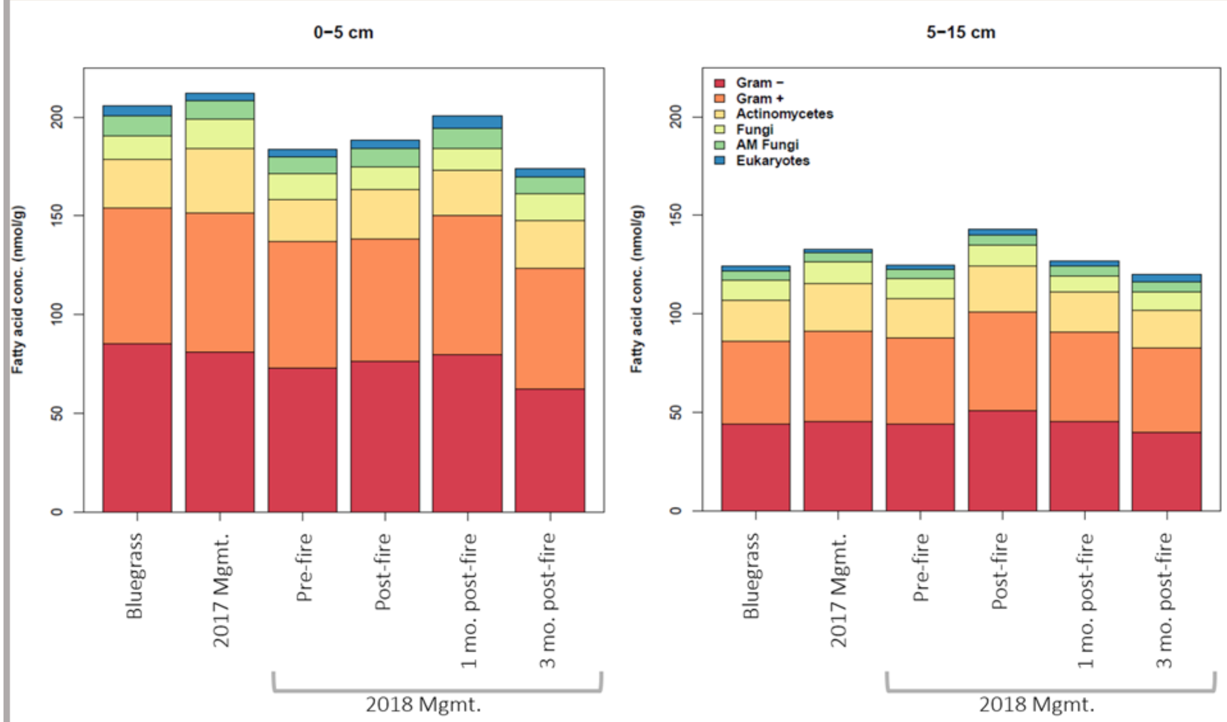

Fig. 3 Microbial community distribution for each treatment and depth based on absolute abundance of membrane lipids. Group means were not statistically different across treatments, within a depth.

Conclusion

In preliminary analysis of data, this research showed no conclusive evidence that bluegrass dominance or associated land management techniques strongly influence soil carbon and nitrogen pools, or microbial community structure and abundance. Soil abiotic characteristics, such as moisture and temperature, may be more important than litter chemistry in driving soil nutrient pools and microbial populations.

Future directions for this research include analysis of decomposition rates among treatments through in-situ litterbag incubations. Decomposition is an important ecosystem function that links below-ground and above-ground processes. Results may provide insight into whether the function of the soil microbial community is impacted by bluegrass dominance or land management practices.

Despite no clear indication from this research that bluegrass is affecting soil nutrient or microbial properties, the larger ecological threat from bluegrass remains the widespread loss of above-ground biodiversity. Understanding of how bluegrass effects below-ground properties remains limited and certainly warrants additional research.

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