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Grazing Management, Season, and Drought Contributions to Near-Surface Soil Property Dynamics in Semiarid Rangeland

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Abstract

Grazing management effects on soil property dynamics are poorly understood. A study was conducted to assess effects of grazing management and season on soil property dynamics and greenhouse gas flux within semiarid rangeland. Grazing management treatments evaluated in the study included two permanent pastures differing in stocking rate (moderately and heavily grazed pastures) and a fertilized, heavily grazed crested wheatgrass (*Agropyron desertorum* [Fisch. ex. Link] Schult.) pasture near Mandan, North Dakota. Over a period of 3 yr, soil properties were measured in the spring, summer, and fall at 0–5 cm and 5–10 cm. Concurrent to soil-based measurements, fluxes of carbon dioxide, methane, and nitrous oxide were measured on 1-wk to 2-wk intervals and related to soil properties via stepwise regression. High stocking rate and fertilizer nitrogen (N) application within the crested wheatgrass pasture contributed to increased soil bulk density and extractable N, and decreased soil pH and microbial biomass compared to permanent pastures. Soil nitrate nitrogen tended to be greatest at peak aboveground biomass, whereas soil ammonium nitrogen was greatest in early spring. Drought conditions during the third year of the study contributed to nearly two-fold increases in extractable N under the crested wheatgrass pasture and the heavily grazed permanent pasture, but not the moderately grazed permanent pasture. Stepwise regression found select soil properties to be modestly related to soil–atmosphere greenhouse gas fluxes, with model r^2 ranging from 0.09 to 0.76. Electrical conductivity was included most frequently in stepwise regressions and, accordingly, may serve as a useful screening indicator for greenhouse gas "hot spots" in grazing land.

Key Words: electrical conductivity, greenhouse gas emissions, Northern Plains, soil acidification

INTRODUCTION

Rangeland soils perform critical functions affecting both forage production and environmental regulation (Follett and Reed 2010; Teague et al. 2011). Rangeland soils are also looked upon to serve as a foundation for ecosystem resilience under increasingly dynamic weather and market conditions (Westoby et al. 1989; Dougill et al. 1998). Accordingly, strategic-minded land managers recognize the importance of soil as a cornerstone of sustained profitability and long-term ecosystem health (Darnhofer et al. 2010), and thereby value information related to its management under changing circumstances.

Limited plant and litter cover over the soil coupled with highly sensitive plant communities make near-surface soil conditions in semiarid rangelands particularly susceptible to change. Management-related influences often serve to exacerbate soil property dynamics in semiarid rangelands (Steffens et al. 2008), with concomitant effects on critical ecosystem services (Daly et al. 1997). Grazing, the predominant use of semiarid rangelands, can variably impact soil properties depending on the frequency, intensity, and duration of livestock influence. Long-term overgrazing has been shown to deteriorate soil physical and chemical properties in semiarid rangelands, contributing to decreased water retention, increased erosion, and enhanced soil nutrient depletion (Chen et al. 2011; Teague et al. 2011). Conversely, good grazing management practices in semiarid rangelands can create soil conditions with improved nutrient cycling and hydrological attributes (Thurow 1991; Banerjee et al. 2000; Ingram et al. 2008).

Understanding of grazing management impacts on soil properties can be captured through single "snapshot" evaluations, assuming treatment features have had adequate time to influence soil condition. Conclusions from such evaluations, however, must be tempered by the inherent limitation of single point-in-time measurements, which—depending on the soil property—may not adequately characterize treatment effects over a growing season or between years, where weather-induced influences on soil condition can be significant (Chen et al. 2001; Whalen et al. 2003). Studies evaluating management influences on soil properties within growing seasons and across consecutive years in semiarid rangelands are needed to provide insight into ecosystem resilience, particularly if the study period encompasses extreme weather conditions.

Given this context, we sought to evaluate near-surface soil property dynamics in three long-term grazing management systems in central North Dakota. Evaluations were conducted three times during the growing season over three consecutive years. To leverage information emanating from the concurrent

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