Soil Response to Long-term Grazing in the Northern Great Plains

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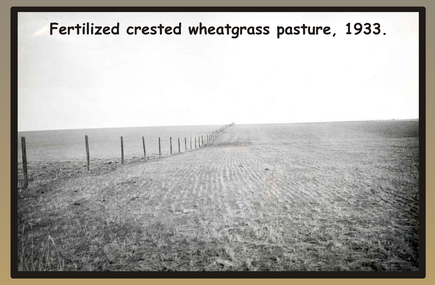
INTRODUCTION

Grazing management influences numerous soil functions, including regulation of greenhouse gas flux. Understanding the effects of grazing management on soil condition and greenhouse gas flux is important for both sustained productivity and environmental quality.

Livestock grazing is an important agricultural enterprise throughout the northern Great Plains. Long-term grazing trials were established in 1916 and 1932 at the USDA-ARS Northern Great Plains Research Laboratory to assess the effects of grazing management on livestock performance, grassland ecology, and soil condition.

The objective of this project was to determine the effects of long-term grazing on soil properties and N_2O emission within a moderately-grazed pasture, heavily-grazed pasture, and a fertilized crested wheatgrass pasture in the northern Great Plains.

This project was conducted as part of the USDA-ARS GRACEnet research effort, which seeks to address scientific issues related to agricultural carbon sequestration and greenhouse gas emission reduction.



Fertilized crested wheatgrass pasture, 1933.

METHODS

Site characteristics

Landscape and soil

The site is on gently rolling uplands (0-3% slope) with a silty loess mantle overlying till. The predominant soil at the site is a Wilton silt loam (fine-silty, mixed, superactive frigid Pachic Haplustoll).

Grazing management systems

Moderately-grazed pasture (**MGP**). Established in 1916. Includes a mix of blue grama [Bouteloua gracilis (H.B.K.) Lag. Ex Griffiths], needle-and-thread (Stipa Comata Trin. and Rupr.), western wheatgrass [Pascopyrum smithii (Rybd) Löve], prairie junegrass [Koeleria pyramidata (Lam) Beauv.], Kentucky bluegrass (Poa pratensis L.), and carex (Carex filifolia Nutt. and Carex heliophila Mack.). Grazed at 2.6 ha steer^{-1}.

Heavily-grazed pasture (**HGP**). Established in 1916. Composed of blue grama and carex. Grazed at 0.9 ha steer^{-1}.

Crested wheatgrass pasture (**FCWGP**). Established in 1932. Dominated by crested wheatgrass [Agropyron desertorum (Fisch. ex. Link) Schult.] and blue grama. Grazed at 0.9 ha steer^{-1}. Receives 45 kg N ha^{-1} annually.

Soil sampling and analysis

Soil samples collected at four sites in each pasture to 100 cm (0-5, 5-10, 10-20, 20-30, 30-60, and 60-100 cm), October 2003. Samples analyzed for soil pH, exchangeable cations, total C and N, inorganic C, and particulate organic matter C and N.

N_2O monitoring

N_2O emission monitored at six sites in each pasture from October 2003 through September 2004 following static chamber methodology.

Samples collected weekly during growing season (April-October); every other week during dormant season (November-March).

Sampling frequency increased following precipitation events and during mid-winter thaws.

Statistical analyses

Grazing management effects on soil properties and integrated annual N_2O emission were evaluated using PROC MIXED at $P<0.05$. Pearson correlation coefficients were calculated to identify associations between soil properties and N_2O emission.

RESULTS

Soil bulk density, Soil pH, Exchangeable cations

Soil depth (cm)	FCWGP	HGP	MGP
	- - - - Soil bulk density (Mg m^{-3}) - - - -		
0-5	1.02 a†	0.92 b	0.87 b
5-10	1.34 a	1.14 b	1.20 ab
10-100	(no differences among pastures)		
	- - - - - - - Soil pH (-log[H$^+$]) - - - - - - -		
0-5	5.10 a	6.62 b	6.44 b
5-10	5.80 a	6.65 b	6.46 b
10-20	6.39 a	6.70 b	6.63 b
20-100	(no differences among pastures)		
	- - - Exchangeable Ca^{+2} (cmol$_c$ kg^{-1}) - - -		
0-5	6.39 b	12.06 a	11.37 a
5-100	(no differences among pastures)		
	- - - Exchangeable Mg^{+2} (cmol$_c$ kg^{-1}) - - -		
0-5	2.64 c	4.84 a	4.50 b
5-10	4.35 b	5.01 a	4.49 b
10-100	(no differences among pastures)		

† Means in a row with unlike letters differ ($P<0.05$).

Soil bulk density was greatest in FCWGP and least in HGP at 0-10 cm. Differences in soil cover among grazing treatments likely influenced trends in soil bulk density.

Acidification from N fertilization resulted in lower soil pH and decreased levels of exchangeable Ca^{+2} and Mg^{+2} in FCWGP as compared to HGP and MGP.

Soil organic C, Total N, Particulate organic matter

Soil depth (cm)	FCWGP	HGP	MGP
	- - - - - Soil organic C (Mg ha^{-1}) - - - - -		
0-5	28.6 a†	28.4 a	22.8 b
5-10	16.7 b	19.1 a	16.7 b
10-20	26.0	26.4	24.2
20-30	20.9	19.4	18.4
30-60	44.1 a	37.1 b	36.6 b
60-100	48.2	45.9	48.6
	- Particulate organic matter C (Mg ha^{-1}) -		
0-5	11.20 a	3.54 b	3.15 b
5-10	1.62 a	1.26 ab	0.94 b
10-20	1.63 a	1.17 b	0.97 b
20-30	1.37 a	0.83 b	0.87 b

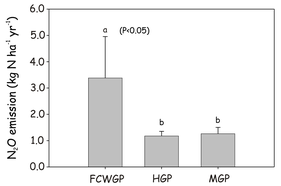
† Means in a row with unlike letters differ ($P<0.05$).

In surface soil (0-10 cm), soil organic C was greatest in HGP among pastures. At deeper soil depths (30-60 cm), soil organic C was greatest in FCWGP. Differences in root distribution among plant species affected trends in soil organic C across depths.

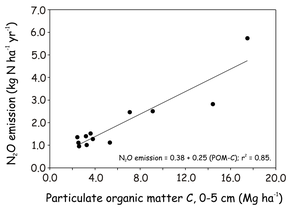
Grazing management affected total N at 0-5 cm (FCWGP=HGP>MGP) ($P<0.05$), but did not affect soil inorganic C at any depth (data not shown).

Particulate organic matter was greatest in FCWGP and least in MGP. Differences in biomass production and levels of decomposed plant material likely contributed to trends in particulate organic matter.

N_2O emission



Annual N_2O emission from FCWGP was more than twice that than from HGP and MGP.



Annual N_2O emission was positively associated with particulate organic matter C across all grazing treatments ($P<0.0001$).

DISCUSSION

Results from this study suggest fertilized crested wheatgrass enhances deep storage of soil organic C, but contributes to surface acidification and greater N_2O emission relative to native vegetation pastures in the northern Great Plains. Differences in soil organic C and total N between native vegetation pastures were brought about by grazing-induced changes in species composition over time.

Particulate organic matter is composed of plant material in an intermediate state of decomposition. This material is generally unprotected by soil particles, resulting in a short turnover time. The positive relationship between particulate organic matter and N_2O emission indicates the potential use of residue-associated organic matter pools as predictors of N_2O emission in grazing management systems.

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Fertilized crested wheatgrass pasture, 2005.