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IMPACT OF GRAZING MANAGEMENT STRATEGIES ON CARBON SEQUESTRATION IN A SEMI-ARID RANGELAND, USA

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Abstract

The effects of 12 years of grazing management strategies on carbon (C) distribution and sequestration were assessed on a semi-arid mixed-grass prairie in Wyoming, USA. Five grazing treatments were evaluated: non-grazed exclosures; continuous, season-long grazing at a light (22 steer-days ha^{-1}) stocking rate; and, rotationally-deferred, short-duration rotation, and continuous, season-long grazing, all three at a heavy stocking rate (59 steer-days ha^{-1}). Non-grazed exclosures exhibited a large buildup of dead plant material (72% of total aboveground plant matter) and forb biomass represented a large component (35%) of the plant community. Stocking rate, but not grazing strategy, changed plant community composition and decreased surface litter. Light grazing decreased forbs and increased cool-season mid-grasses, resulting in a highly diversified plant community and the highest total production of grasses. Heavy grazing increased warm-season grasses at the expense of the cool-season grasses, which decreased total forage production and opportunity for early season grazing. Compared to the exclosures, all grazing treatments resulted in significantly higher levels of C (6000-9000 kg ha^{-1}) in the surface 15 cm of the soil. Higher levels of soil C with grazing are likely the result of faster litter decomposition and recycling, and redistribution of C within the 0-60 cm plant-soil system. Grazing at an appropriate stocking rate had beneficial effects on plant composition, forage production, and soil C sequestration. Without grazing, deterioration of the plant-soil system is indicated.

Keywords: Carbon balance; mixed-grass prairie

Introduction

Land grazed by domestic livestock and/or wildlife occupies about 3 billion hectares worldwide (Schuman et al., 2000), and contains large reserves of C, which represent an important, but often overlooked, component of terrestrial C. With levels of atmospheric CO_2 projected to increase in the coming decades, an understanding is needed of how different grazing management strategies might affect the potential for grazing lands to sequester C. In grazed ecosystems, about 90% of total system C usually is stored in soil organic matter, which is the largest and most stable pool of C in terrestrial ecosystems (Schuman et al., 1999). Changes in the amount and distribution of C stored in soil occur in response to grazing management, but the mechanisms involved are not clearly defined. The purpose of this study was to evaluate the effects of different grazing management strategies on C distribution and sequestration in a mixed-grass prairie near Cheyenne, Wyoming, USA.

Material and Methods

Grazing treatments were established on a native mixed-grass prairie that had not been grazed by domestic livestock for over 40 years. The site is at 1925 m elevation, with 127-day growing season and 338 mm average annual precipitation. Average peak standing crop (PSC) vegetation composition at the beginning of the study was 42% C_3 species, predominately western wheat grass *(Pascopyrum smithii*) and needleandthread (*Stipa comata*); 45% C_4 species, predominately blue grama (*Bouteloua gracilis*), and 13% forbs. Five grazing strategy-stocking rate treatment combinations were established in a randomized block design with two replicate pastures of each treatment. Grazing treatments were: non-grazed exclosures; continuous, season-long grazing by yearling steers at a light stocking rate (22 steer-days ha^{-1}); and, rotationally-deferred, short-duration rotation, and continuous, season-long grazing, all at a heavy stocking rate (59 steer-days ha^{-1}). Twelve years after establishing the grazing treatments, soil and plant samples were collected at PSC from five replicate sample locations along permanent transects in each pasture. Transects were all located on near-level sites on an Ascalon sandy loam soil. Soil cores (4.6 cm diam.) and root biomass cores (9.9 cm diam.) were collected to 60 cm, and aboveground plant components were estimated by clipping within 0.18 m^2 frames. Soil organic C was determined by the Walkley-Black procedure (Nelson and Sommers 1982), and plant C was assessed with a Carlo-Erba automated analyzer. All concentration data were converted to mass basis for evaluation.

Results and Discussion

Twelve years after initiating the study, all treatments resulted in shifts in plant community composition at PSC. In the fenced exclosures, forb biomass increased by 23% while warm-season grasses decreased by 28%. Grazing at the light stocking rate resulted in the lowest forb biomass and highest cool-season grass biomass (Figure 1), producing a highly diverse plant community and the highest total production of grasses. In comparison to light grazing, the proportions of warm-season grasses and forbs were higher, and cool-season grasses lower with the heavy stocking rate, resulting in lower total forage production. The effect of the heavy stocking rate on plant community composition was not significantly different among the three grazing strategies.

After over 40 years of excluding both fire and livestock, twelve years of grazing changed the distribution of C among system components compared to the exclosures (Table 1). Non-grazed exclosures exhibited a large buildup of C in litter and standing dead plant material (63% of above ground plant C). All grazing treatments decreased the levels C in plant litter on the soil surface, and increased levels of C (6000-9000 kg ha^{-1}) in the surface 15 cm of the soil. Increased soil C with grazing is likely due to increases in C cycling from aboveground plant residues into the soil, and redistribution of C within the plant: soil (0-60 cm) system due to changes in the plant community composition (Schuman et al., 1999). Grazing also may increase soil C by stimulating root respiration and root exudation of C into the soil (Dyer and Bokhari, 1976). In this study, changes in plant community with grazing were not detected as significant changes in root biomass or root C mass, probably because of the high variability in root biomass. However, the increase in (0-15 cm) soil C with the light stocking rate can be attributed in part to the low percentage of forbs and high percentage of grasses in the plant community, because the dense fibrous rooting systems of grasses contribute more to the formation of soil organic matter than do the taproot systems of forbs. Similarly, the increase in (0-15 cm) soil C with the heavy stocking rate may be largely the result of the lower proportion of C_3 mid-grasses and higher proportion of blue grama, a C_4 short-grass which concentrates root biomass in the surface 15 cm, has a higher root: shoot ratio and transfers more C belowground than do mid-grass species (Schuman et al., 1999).

The grazing-induced increase in C stored in the surface 15cm of the soil was not reflected in a significant increase in the total mass of C in the plant-soil system (0-60 cm depth). All grazing treatments were numerically higher (3000-11,000 kg ha^{-1}) in total system C than the nons-grazed treatment, but because of the complex and highly variable soil and plant community, we were unable to detect significant gains of system C with grazing. Grazing also had no apparent effect on system CO_2 exchange rates (LeCain et al., 2000). However, incorporation of aboveground C into the surface 15 cm of the soil increases the potential for conservation of existing system C, and enhances nutrient cycling as well as the sustainability and productivity of the plant community since the majority of plant roots reside at this depth. An appropriate level of grazing prevents deterioration of the plant community, provides an economic productivity from the land, and optimizes C storage in the soil.

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Tables and Figures

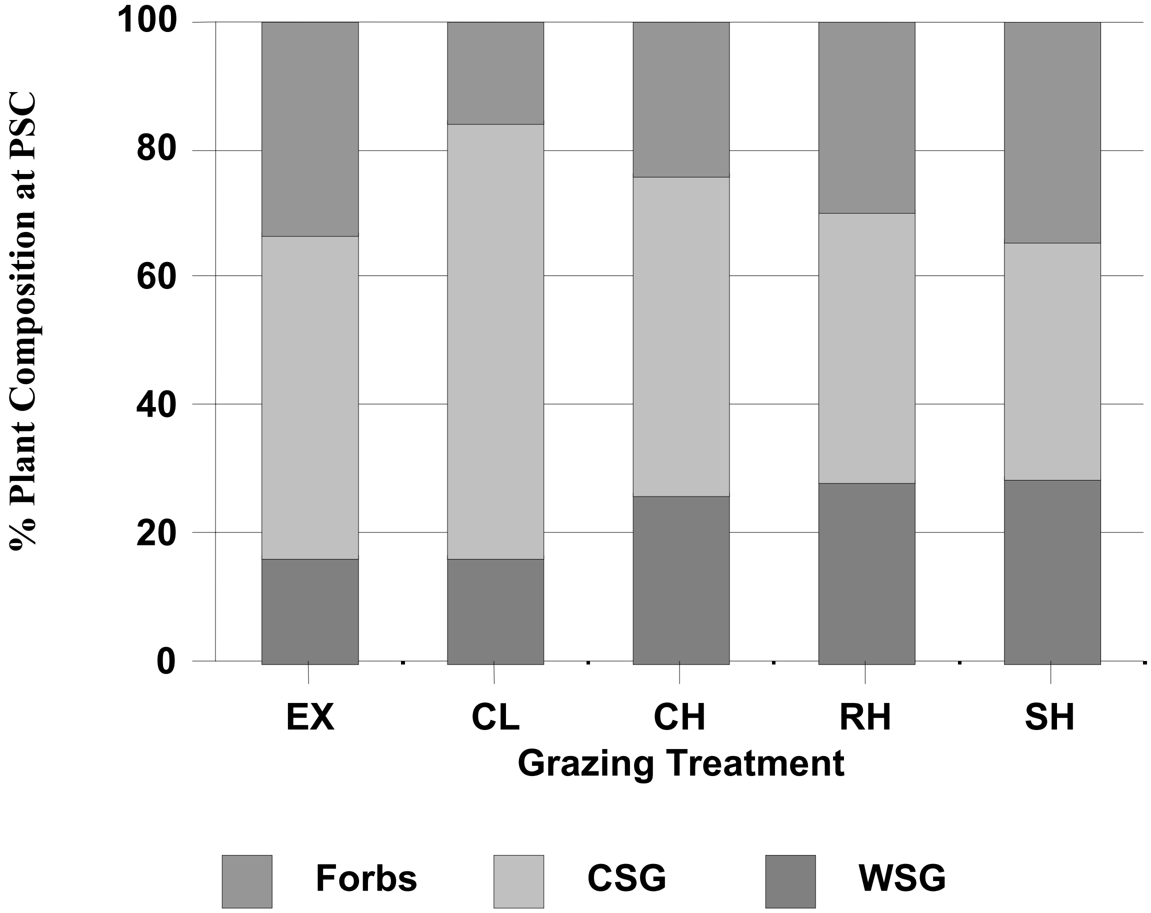

Figure 1 – Botanic composition (biomass at peak standing crop) after 12 years of grazing. EX = non-grazed exclosures, L = light stocking rate (22 steer-days ha^{-1}), H = heavy stocking rate (59 steer-days ha^{-1}), C = continuous, season-long grazing, R = 4-pasture-rotationally-deferred grazing, and S = 8-paddock short-duration rotation. Warm-season grasses (WSG) $LSD_{.05}$ = 9.6%; cool-season grasses (CSG) $LSD_{.05}$ = 12.7%; forbs $LSD_{.05}$ = 12.1%.

Table 1 - Mass of C (kg/ha) from vegetation components and soil (0-60 cm profile) between grazing strategies and stocking rate.

	Exclosure	Continuous Light[1]	Continuous Heavy[2]	Rotationally Deferred Heavy	Short-Duration Heavy	$LSD_{0.05}$
Plant Components						
Live Biomass	587	535	355	443	470	111
Standing Dead	206	209	0	0	0	60
Litter	809	533	394	441	345	258
Total aboveground C	1602	1277	749	884	815	228
Roots:						
0-15 cm	7,166	6,011	5,763	5,924	6,242	ns
15-30 cm	1,244	1,646	1,312	1,663	1,747	ns
30-60 cm	379	504	346	368	185	199
Roots: (total)	(8,789)	(8,161)	(7,421)	(7,955)	(8,174)	ns
TOTAL PLANT C	10,391	9,438	8,170	8,839	8,989	ns
Soil Profile, cm						
0 - 3.8	9,595	12,675	12,000	11,891	12,582	1028
3.8 - 7.6	5,906	7,457	8,478	8,606	8,880	729
7.6 - 15	12,661	15,009	15,472	13,709	16,138	1714
TOTAL SOIL C, 0-15	28162	35141	35950	34206	37601	2989
15 - 30	19,761	22,847	22,348	17,999	22,222	2794
30 - 46	22,932	20,353	25,281	21,185	21,471	ns
46 - 60	17,291	13,595	17,689	19,114	13,332	ns
TOTAL SOIL C, 0-60	88,147	91,937	101,267	92,504	94,625	ns
TOTAL CARBON	98,538	101,374	109,437	101,343	103,614	ns

[1] Light stocking rate = 20 steer days ha^{-1}, [2] Heavy stocking rate = 59 steer days há