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Grazing Cover Crops Improved Soil Health in Dryland Cropping Systems

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Grazing Cover Crops Improved Soil Health in Dryland Cropping Systems

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Summary

Integrating cover crops (CCs) in dryland crop production in the semiarid central Great Plains (CGP) can provide several ecosystem benefits. However, CC adoption has been slow in the CGP because CCs utilize water that otherwise would be available for the subsequent cash crop. Grazing CCs can provide economic benefits to offset revenue loss associated with decreased crop yields when CCs are grown ahead of a cash crop. Field experiments were conducted from 2015 through 2022 to quantify effects of grazing CCs on soil bulk density, aggregate stability, and chemical properties across western Kansas. At the Kansas State University HB Ranch near Brownell, KS, grazed CCs were compared to non-grazed CCs and fallow in a wheat-sorghum-fallow rotation. The on-farm study evaluated CCs grazed with yearlings or cow-calf pairs compared to non-grazed CCs across seven site-years on producer fields in western Kansas (Alexander and Hays) and central Kansas (Marquette). Averaged across 8 years, hayed and grazed CCs removed 71% and 40%, respectively, of available CC biomass at Brownell. Across on-farm sites, CC residue after grazing averaged 2210 lb/a compared to 3475 lb/a for the non-grazed CCs, representing a 36% decrease in CC biomass with grazing. Grazing days across farms ranged from 25 to 54 days with average daily gain of 1.2 to 3.11 lb/d. Soil characteristics including bulk density, penetration resistance, aggregate size distribution, and mean weight diameter (MWD) of water stable aggregates were not different between grazed and non-grazed CCs. Cover crops tended to increase soil organic carbon (SOC) concentration compared to fallow or initial SOC levels in some site-years. For example, SOC measured at the surface 0- to 2-inch depth near Hays, KS, in spring 2019 was 1.4%, which was significantly less than the 2.1% SOC measured in 2021 after two cycles of grazing CCs at this location. Penetration resistance measured after grazing in 2021 averaged 52.2 and 49.3 psi for the grazed and non-grazed CCs at Marquette, KS. Similarly, penetration resistance averaged 75.4 psi with grazed and non-grazed CCs at Alexander, KS. The penetration resistance measured across locations and CC management strategies was below the threshold of 300 psi that will limit root growth. Based on findings of this study, integrating CCs with livestock can be a strategy for producers to balance profitability and soil health in dryland crop production in western Kansas.

Introduction

Cropping system diversification with CCs can provide several benefits. These include improving soil quality, nutrient cycling, weed and pest suppression, and reduced wind erosion (Obour et al., 2021). Cover crop adoption is not widely popular in water-limited environments because CCs utilize water that otherwise would be available to the subsequent cash crop. Grazing CCs can provide economic benefits and help offset loss in revenue associated with decreases in wheat yields when cover crops are grown in place of fallow. This approach could provide an opportunity for dryland producers to build soil health and produce harvestable forage for the region's livestock (Holman et al., 2021; Obour et al., 2021).

The few growers that have adopted CC in dryland systems are using them not only for soil health improvement but also as a supplemental forage resource. Most CC species can provide high-quality forage, which can extend the grazing season for livestock and delay grazing of native perennial grasslands. Information is limited on the effects of grazing CCs on crops and soil health in dryland systems, which necessitates the current research. The objectives of this study were to 1) determine forage production of CC crop mixtures, and 2) evaluate the impacts of grazing CCs on residue cover, soil health, and subsequent crop yields.

Experimental Procedures

Cover biomass, residue cover, and soil properties data presented herein are from field experiments conducted on farmer fields across western Kansas and at the Kansas State University HB Ranch near Brownell, KS, from 2015 through 2021 (Simon et al., 2021). The experimental design of the study near Brownell (22 inches annual precipitation) was a split-plot randomized complete block with four replications. Main plots were three crop phases of the wheat-sorghum-fallow crop rotation, split-plots compared grazed, hayed, non-grazed CCs, and fallow. In this study, spring CCs (oats and triticale) were planted into sorghum residues. Every year, CCs were stocked between late May and early June with yearling heifers at a stocking rate of about 775 lb/a. A second study was initiated in 2018 on producer fields near Alexander, Hays, and Marquette, KS, to further test the effects of grazing CCs on soil properties. At these locations, grazed CCs were compared to non-grazed CCs. Whole fields at Alexander and Hays were 80 and 50 acres, respectively, and were considered western locations (22 to 24 inches average annual precipitation). Whole fields at Marquette were 80–90 acres and were considered central locations (28 to 30 inches average annual precipitation). Across on-farm sites, four areas within each field were assigned as fenced zones to exclude grazing (non-grazed treatment) and cattle were allowed full access to the adjacent unfenced areas (grazed treatment).

The field at Alexander was under a no-till (NT) winter wheat-corn-fallow rotation. In 2019, spring CCs (oats, triticale, barley, pea, rapeseed, and sunflower) were planted into corn residues and grazed with yearlings from May 14 to June 14 at a stocking rate of about 350 lb/a. In 2020, summer CCs (sorghum-sudangrass, German millet, sunn hemp, sunflower, and radish) were planted immediately after wheat harvest and grazed with yearlings from August 7 to September 18 at a stocking rate of 575 lb/a. At Hays, the field was managed under a NT winter wheat-grain sorghum-fallow rotation, and CC mixtures were the same as described for Alexander at similar points in the rotation. In 2019, summer CCs were planted immediately after wheat harvest and grazed with cow-calf pairs from August 24 to October 10 at a stocking rate of about 350 lb/a. In 2021, spring CCs were planted into grain sorghum residues and grazed with yearlings from June 30 to July 20 at a stocking rate of 550 lb/a. At Marquette, the field was managed under a NT winter wheat-wheat-soybean rotation, and fall CCs (triticale, rapeseed, and radish) were planted into wheat residues. In 2018–2019, yearlings grazed from December 17 to February 10 at a stocking rate of 550 lb/a. In 2020–2021, yearlings (575 lb each) grazed from January 1 to February 14 at a stocking rate of 550 lb/a.

Cover crop biomass was determined at pre- and post-grazing at each site. Additionally, soil samples were collected at 0- to 2-inch and 2- to 6-inch depths at each site to determine bulk density, SOC, and aggregate stability at the time of grain crop planting following CCs. In 2021 at Alexander and Marquette, penetration resistance was measured at 10 random points within each plot using a hand cone penetrometer (Eijkelkamp Co., Giesbeek, Netherlands) and readings were divided by the area of the cone. Values of penetration resistance were adjusted to a field capacity gravimetric water content. Statistical analyses were completed using PROC GLIMMIX of SAS v. 9.3 (SAS Institute, Cary, NC) with year, treatment, and their interactions considered fixed when appropriate for each study, and replication was always considered random. Treatment differences were considered significant at $P \leq 0.05$.

Results and Discussion

Cover crop productivity varied over the study period because of variations in soil water availability and air temperature in the spring. At Brownell, non-grazed CC biomass ranged from 1900 lb/a in 2019 to 4900 lb/a in 2015 (Figure 1). The lower CC forage mass production in 2019 was due to wet spring conditions that delayed CC planting. In 2019 and 2021 when there was time for regrowth before CC termination, biomass left after grazing was similar to that measured pre-grazing. Residue left post-grazing averaged 60% of biomass of the non-grazed CC and 75% of pre-grazing CC biomass across the 8-year study at Brownell, KS (Figure 1).

Cover crop biomass after grazing at Alexander, KS, (spring planted) and Marquette, KS, (fall planted) were not different from biomass measured before grazing (Table 1). This result suggested there was significant regrowth from the cool season CCs. However, the post-grazed biomass was less than that of non-grazed CC in most cases. Grazing days across farms ranged from 25 to 54 days with an average daily gain of 1.2 to 3.11 lb/d. Across the seven on-farm site-years, CC residue after grazing averaged 2210 lb/a compared to 3475 lb/a for the non-grazed CCs, representing a 36% decrease in CC biomass with grazing. Therefore, careful grazing of CCs can leave adequate amounts of residue to protect the soil to achieve soil health goals while providing a forage resource for livestock.

Grazing or haying CCs had no significant effect on soil bulk density measured in 2019 and 2020 in Brownell, KS. Across years, fallow, non-grazed CCs, and grazed CCs had soil bulk densities of 1.11, 1.15, and 1.15 g/cm^3 at the 0- to 2-inch soil depth and 1.39, 1.40, and 1.37 g/cm^3 at the 2- to 6-inch soil depth, respectively. The SOC concentrations in the 0- to 2-inch soil depth with hayed CCs (1.51%) were smaller compared to grazed CCs (1.64%) or the non-grazed CCs (1.65%) and both were similar to fallow (1.52%; Figure 2a). This showed that grazing CCs can maintain or accrue SOC similarly to non-grazed CCs in dryland systems. However, haying CCs could have detrimental effects on SOC concentrations because less residue was retained following CC forage removal. The MWD of water stable aggregates in the 0- to 2-inch soil depth was greater with all CCs (standing, grazing, or hayed) compared to fallow (Figure 2b). This indicates that CCs have the ability to increase soil aggregation similarly when standing, hayed, or grazed. Additionally, all CCs were found to increase the proportion of large macroaggregates (>0.08-inch) compared to fallow.

At Alexander and Hays, soil bulk density, SOC and MWD of water stable aggregates were not different between grazed and non-grazed CCs (Table 2). However, compared to the initial measurements, CCs had significantly greater SOC concentrations, particularly at Hays (Table 2). The MWD of water stable aggregates at Hays in 2021 averaged 0.06 inches with grazed and 0.08 inches for non-grazed CCs. Similarly, at Alexander, MWD measured in 2021 was unaffected by grazing CCs (Table 2). Wind-erodible fraction was not different between CC treatments. Penetration resistance at the 0- to 6-inch soil depth averaged 75 psi with grazed CCs, which was not different compared to non-grazed CCs.

At Marquette, measured soil properties were not different between grazed and non-grazed CCs. Soil bulk density measured within the top 0- to 2-inch in grazed plots averaged 1.23 g/cm^3 compared to 1.43 g/cm^3 for the non-grazed treatment in 2019 (Table 2). The bulk density measured in this same field in 2021 averaged 1.38 g/cm^3 for grazed and 1.36 g/cm^3 for the non-grazed treatment in the 0- to 2-inch depth. The bulk density measured at 2- to 6-inch depth was 1.53 g/cm^3 for grazed and 1.49 g/cm^3 for the non-grazed treatment. The penetration resistance measured after grazing in 2021 averaged 52 and 49 psi with grazed and non-grazed CCs, respectively, at Marquette. The measured penetration resistance across locations and CC management strategies was below the threshold of 300 psi that will limit root growth. The SOC concentration after two cycles of CC measured in the top 0- to 2-inch depth in 2021 averaged 1.74% with grazed CCs and 1.62% for non-grazed. The SOC at 2- to 6-in. depth was unaffected by CC management and averaged 1.22% and 0.97% for grazed and non-grazed CCs, respectively (Table 2). Findings of this research showed CCs can be grazed in dryland cropping systems with no negative effects on soil properties compared to non-grazed CCs, and with improved soil health compared to fallow.

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Table 1. Cover crop biomass (grazed and non-grazed) at Alexander, Hays, and Marquette, KS, from 2019 to 2021

Cover crop treatment	Alexander, KS		Hays, KS		Marquette, KS		
	2019	2020	2019	2021	2019	2020	2021
	Cover crop biomass, lb/a						
Pre-graze	1337 ab	3948 b	6158 a†	1063 b	1262 b	955 b	2136 b
Post-grazing	1000 b	3734 b	4744 b	429 c	1292 b	2068 a	2207 b
Non-grazed	2304 a	5189 a	6908 a	1436 a	2740 a	2653 a	3100 a

†Means in a row followed by different letters indicate significant differences among cover crop management at $\alpha < 0.05$.

Table 2. Cover crop grazing effects on soil bulk density (BD), soil organic carbon (SOC), mean weight diameter (MWD) of aggregates, wind erodible fraction (WEF), and penetration resistance (PR) at Alexander, Hays, and Marquette, KS

Location	Depth, in.	Treatment	BD	SOC	WEF	MWD	PR
			g/cm^3	%	%	inches	psi
Alexander, KS	0–2	2019 Initial	1.02b†	0.98a		0.05a	
		2021 Grazed	1.36a	1.11a	11.9a	0.06a	75.4a
		2021 Non-grazed	1.36a	1.10a	14.1a	0.06a	75.4a
	2–6	2019 Initial	1.29a	1.12a			
		2021 Grazed	1.41a	1.22a	11.1a	0.04a	75.4a
		2021 Non-grazed	1.44a	1.03a	18.4a	0.04 a	75.4a
Hays, KS	0–2	2019 Initial	1.24a	1.38c		0.07a	
		2020 Grazed	1.32a	1.89b		0.06a	
		2020 Non-grazed	1.20ab	2.05ab		0.08a	
		2021 Grazed	1.09b	2.05a	16.4a	0.08a	
		2021 Non-grazed	1.04b	1.95ab	20.9a	0.06 a	
	2–6	2019 Initial	1.43a	1.35c			
		2020 Grazed	1.41ab	1.58a			
		2020 Non-grazed	1.38b	1.53ab			
		2021 Grazed	1.13c	1.52ab	13.1a	0.06a	
		2021 Non-grazed	1.13c	1.39bc	11.9a	0.08a	
Marquette, KS	0–2	2018 Initial	1.42a	1.45 b			
		2019 Grazed	1.23b	1.48 b		0.04a	
		2019 Non-grazed	1.43a	1.70 a		0.06a	
		2021 Grazed	1.38ab	1.74 a	15.3a	0.05a	52.2a
		2021 Non-grazed	1.36ab	1.62a	12.4a	0.04a	49.3a
	2–6	2018 Initial	1.52a	1.20 b			
		2019 Grazed	1.49a	1.21 b			
		2019 Non-grazed	1.54a	1.40 a			
		2021 Grazed	1.53a	1.22b	4.5a	0.03a	52.2a
		2021 Non-grazed	1.49a	0.97 c	5.5a	0.03a	49.3a

†Means in a row followed by different letters indicate significant differences among cover crop management at $\alpha < 0.05$.

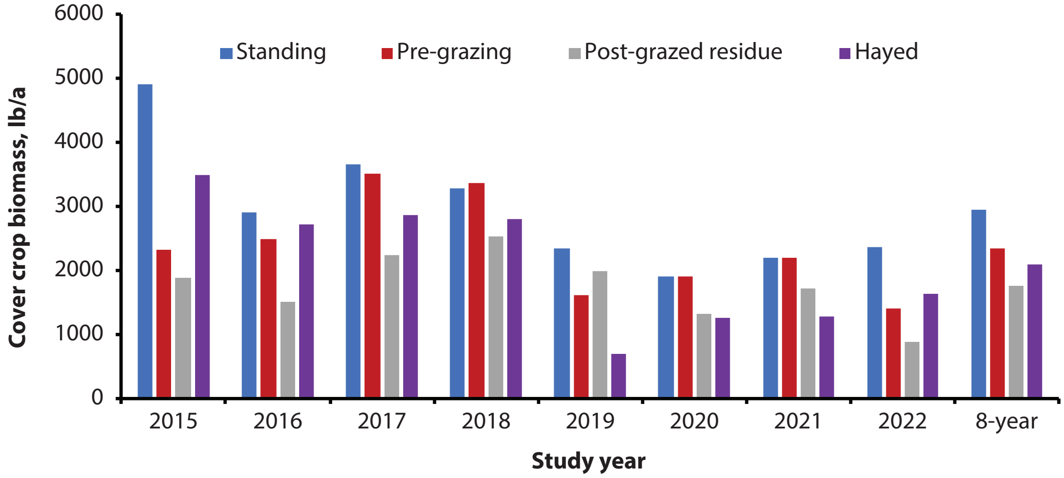

Figure 1. Cover crop productivity from 2015 to 2022 at Kansas State University HB Ranch near Brownell, KS.

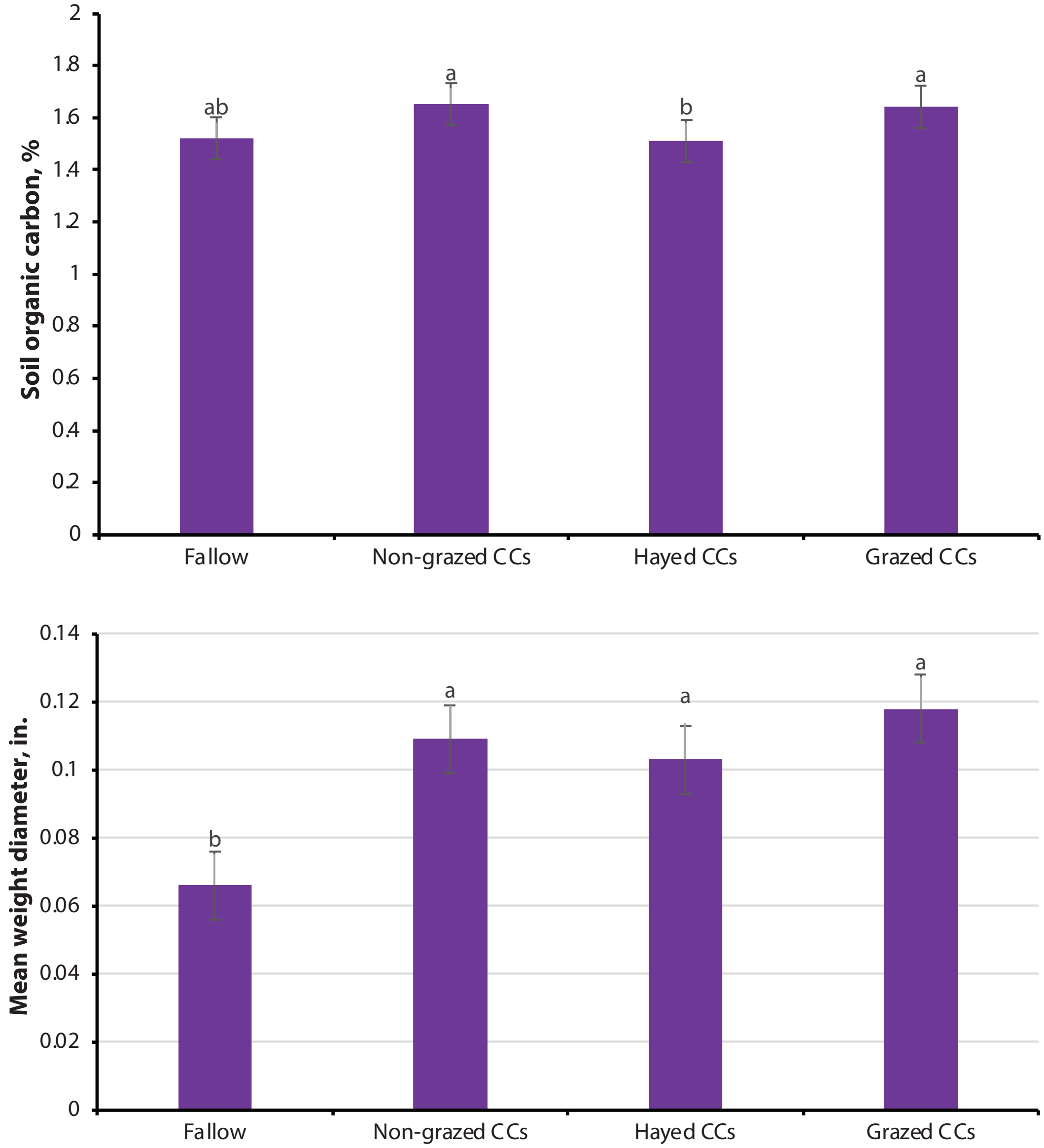

Figure 2. Effects of cover crop management on soil organic carbon (A) and mean weight diameter (B) of water stable aggregates measured in the 0- to 2-inch soil depth in a dryland wheat-sorghum-fallow rotation at Brownell, KS. Error bars indicate standard error of the means and bars with the same letter are not significantly different ($\alpha = 0.05$).