Cover Crop Grazing Effects on Soil Compaction Indicators in Western and Central Kansas

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Summary

Grazing cover crops (CCs) on no-till (NT) croplands in western and central Kansas could increase the profitability of crop production in these water-limited environments. However, little information exists about potential soil compaction associated with grazing CCs in these cropping systems. From 2019 to 2021, two studies investigated the effects of grazing CCs on soil bulk density and penetration resistance in NT cropping systems. At the Kansas State University HB Ranch near Brownell, KS, CCs grazed with yearling heifers were compared to ungrazed CCs and fallow under NT or occasional tillage (OT). In another study, CCs grazed with yearlings or cow-calf pairs were compared to ungrazed CCs across seven site-years on producer fields in western Kansas (Alexander and Hays) and central Kansas (Marquette 1 and 2). Soil bulk density and penetration resistance measurements were made at the time of subsequent grain crop planting following CCs. At Brownell, CC management, tillage, and their interaction had no significant effect ($P > 0.05$) on soil bulk density. Across years, bulk densities with fallow, ungrazed CCs, and grazed CCs were 1.11, 1.15, and 1.15 g/cm^3 at the 0- to 2-inch soil depth, respectively. Soil bulk densities with NT and OT were 1.14 and 1.14 g/cm^3 at the 0- to 2-inch soil depth, respectively. Similarly, CC grazing had no significant effect on soil bulk density and penetration resistance across the seven on-farm sites-years. At the western Kansas locations, soil bulk density averaged 1.23 g/cm^3 at the 0- to 2-inch soil depth with grazed or ungrazed CCs. At the central Kansas locations, soil bulk density averaged 1.31 and 1.36 g/cm^3 at the 0- to 2-inch soil depth for grazed and ungrazed CCs, respectively. Bulk density measured at 2- to 6-inch depth was not different between grazed and ungrazed CC in either study. At Alexander, penetration resistance was 0.52 and 0.52 MPa with grazed and ungrazed CCs, respectively. Penetration resistance was 0.36 and 0.34 MPa with grazed and ungrazed CCs, respectively, at Marquette 1. Results showed that grazing CCs never increased soil bulk density or penetration resistance compared to ungrazed CCs. Based on these findings, grazing CCs on NT fields can be a strategy for producers to balance profitability and soil health.

Introduction

No-tillage (NT) and cover crops (CCs) have been recommended to regenerate soil health degraded after years of conventionally-tilled, low-intensity crop production. Soil health benefits of adopting CCs in the NT cropping systems include increased soil organic carbon, enhanced nutrient cycling, reduced compaction, increased water infiltration, and reduced wind and water erosion. However, establishment costs and the risk of CCs reducing subsequent grain yields present a major barrier to adoption of CCs in water-limited western and central Kansas. Some producers have sought to overcome these factors by integrating livestock (usually cattle or sheep) to graze CCs. Most CC species can provide high-quality forage, which can extend the grazing season for livestock and delay grazing of native perennial grasslands. Based on these benefits, there is motivation for Natural Resources Conservation Service (NRCS) cost-share programs to allow grazing on enrolled CCs to increase producer adoption of CCs.

Despite the potential economic benefits of integrating livestock, there is concern that grazing CCs on NT fields could cause the development of yield-limiting soil compaction that would require tillage to remediate. Little information exists about the effects of grazing CCs on soil compaction in NT cropping systems in Kansas and the central Great Plains region. Experience with crop residue grazing suggests that grazing time, duration, and stocking rates are key considerations to prevent soil degradation. Therefore, the objective of this research was to quantify CC grazing impacts on indicators of soil compaction in NT cropping systems in western and central Kansas.

Procedures

Two studies were conducted from 2019 to 2021 to investigate the effects of grazing CCs on two indicators of soil compaction (soil bulk density and penetration resistance). The first study was initiated in 2015 at the Kansas State University HB Ranch near Brownell, KS. The study compared grazed and ungrazed CCs to fallow under NT or occasional tillage (OT) in a winter wheat-grain sorghum-fallow crop rotation. The study site had a silt loam soil type and averages 22 inches of precipitation annually. The experimental design was a split-split-plot randomized complete block with four replications. Main plots were the three crop phases of the wheat-sorghum-fallow crop rotation; split-plots were grazed CCs, ungrazed CCs, and fallow; and split-split-plots (300 ft^2) were NT and OT. 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 (1000 lb each) at a stocking rate of 775 lb/a. Heifers were moved daily for four days across the four replications. In this study, OT was implemented with a single tillage pass of a QuinStar Fallow Master sweep plow (QuinStar Equipment Company, Quinter, KS) to a depth of 3 inches in July between CC termination and winter wheat planting, but was otherwise managed the same as NT.

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 ungrazed 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 93 (Marquette 1) and 80 acres (Marquette 2), respectively, and were considered central locations (28 to 30 inches average annual precipitation). All locations had silt loam soils. At on-farm sites, four areas of 0.75 to 2.5 acres in size were assigned within each field as fenced zones to exclude grazing (ungrazed plots). Cattle were allowed full access to the adjacent unfenced areas with a single watering area at one end of the field. Grazed areas directly adjacent to the four ungrazed plots and away from the watering area were assigned as grazed plots for a total of eight plots at each location.

At Alexander, the field was managed under a 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 (600 lb each) from May 14 to June 14 at a stocking rate of 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 (750 lb each) 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 (1388 lb/a combined) from August 24 to October 10 at a stocking rate of 350 lb/a. In 2021, spring CCs were planted into grain sorghum residues and grazed with yearlings (575 lb each) from June 30 to July 20 at a stocking rate of 550 lb/a. At Marquette 1, the field was managed under a NT winter wheat-soybean rotation, and fall CCs (triticale, rapeseed, radish) were planted into wheat residues. In 2018–2019, yearlings (600 lb each) 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. At Marquette 2, the field was managed under a NT winter wheat-grain sorghum-soybean rotation, and CCs were the same as described for Marquette 1. In 2019–2020, fall CCs were planted into wheat residues and grazed with yearlings (575 lb each) from January 9 to February 17 at a stocking rate of 550 lb/a.

Soil samples were collected at each site to determine bulk density at the time of grain crop planting following CCs. Two intact soil cores of 6 inches in depth and 2 inches in diameter were collected from each plot. In the grazed plots, care was taken to avoid trails of heaviest cattle traffic. Samples were split into 0- to 2- and 2- to 6-inch increments and dried at 221°F for a minimum of 48 hours. Soil bulk density was computed as mass of oven-dried soil divided by volume of the core. In 2021 at Alexander and Marquette 1, penetration resistance was measured at 10 random points within each plot to a depth of 0–6 inches using a hand cone penetrometer (Eijkelkamp Co., Giesbeek, the Netherlands), and readings were divided by the area of the cone (2 cm^2). Values of penetration resistance were adjusted to a field capacity gravimetric water content of 0.35 (g/g). Statistical analyses were completed using PROC GLIMMIX of SAS v. 9.3 (SAS Institute, Cary, NC) with year, treatment, tillage, 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

At Brownell, the effects of treatment, tillage, and their interaction on soil bulk density were not significant ($P > 0.05$) at the 0- to 2- or 2- to 6-inch soil depths in any year of the study (Table 1). These results indicate that grazing CCs did not cause soil compaction compared to ungrazed CCs or fallow measured at subsequent winter wheat planting. Averaged across years, fallow, ungrazed 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. Additionally, soil bulk density under NT was not different ($P > 0.05$) compared to OT plots (Table 1). Averaged across years, NT and OT had soil bulk densities of 1.14 and 1.14 g/cm^3 at the 0- to 2-inch soil depth and 1.40 and 1.36 g/cm^3 at the 2- to 6-inch soil depth, respectively.

Soil bulk densities across CC management strategies, tillage operations, and soil depths were below the threshold of 1.6 g/cm^3 at which root-limiting compaction begins.

Across the seven on-farm site-years (Table 2), soil bulk density was different between CC treatments only at Marquette 1 in 2019 when bulk density in the 0- to 2-inch soil depth with ungrazed CCs (1.43 g/cm^3) was greater ($P < 0.05$) than grazed CCs (1.23 g/cm^3). At the western Kansas locations, average soil bulk densities with grazed and ungrazed CCs were 1.23 and 1.23 g/cm^3 at the 0- to 2-inch soil depth and 1.35 and 1.34 g/cm^3 at the 2- to 6-inch soil depth, respectively. At the central Kansas locations, soil bulk densities with grazed and ungrazed CCs were 1.31 and 1.36 g/cm^3 at the 0- to 2-inch soil depth and 1.51 and 1.50 g/cm^3 at the 2- to 6-inch soil depth, respectively. Soil bulk densities across all locations, CC management strategies, and soil depths were below the threshold of 1.6 g/cm^3 at which root-limiting compaction begins. Penetration resistance at the 0- to 6-inch soil depth with grazed CCs was not different from ungrazed CCs at both Alexander and Marquette 1 in 2021 (Figure 1). At Alexander, penetration resistance was 0.52 and 0.52 MPa with grazed and ungrazed CCs, respectively. At Marquette 1, penetration resistance was 0.36 and 0.34 MPa with grazed and ungrazed CCs, respectively. The measured penetration resistances across locations and CC management strategies were below the threshold of 2 MPa at which root-limiting compaction begins.

Our results showed that grazing CCs had no negative effects on soil bulk density compared to ungrazed CCs or fallow under NT or OT. Similarly, across seven on-farm site years, neither soil bulk density nor penetration resistance was ever increased with grazing CCs compared to ungrazed CCs. Based on these findings, grazing CCs on NT fields can be a strategy for producers to balance goals of environmental and economic sustainability in water-limited crop production. Allowing grazing of CCs enrolled in the NRCS cost-share programs could increase producer adoption of CCs in western and central Kansas to enhance regional soil health and increase system profitability.

Table 1. Effects of cover crop (CC) management and no-tillage (NT) or occasional tillage (OT) on soil bulk density at the Kansas State University HB Ranch near Brownell, KS

		Bulk density (g/cm^3)		
Treatment	**Tillage**	**2019**	**2020**	**2021**
		0- to 2-inch		
Fallow	NT	1.05a[†]	1.16a	1.17a
	OT	1.02a	1.17a	1.09a
Ungrazed CC	NT	1.07a	1.16a	1.14a
	OT	1.16a	1.18a	1.22a
Grazed CC	NT	1.06a	1.22a	1.20a
	OT	1.14a	1.20a	1.13a
		2- to 6-inch		
Fallow	NT	1.34a	1.39a	1.46a
	OT	1.24a	1.34a	1.41a
Ungrazed CC	NT	1.38a	1.40a	1.43a
	OT	1.32a	1.40a	1.36a
Grazed CC	NT	1.30a	1.38a	1.39a
	OT	1.28a	1.36a	1.35a

[†]Means with the same letter within columns are not different ($\alpha = 0.05$) across treatments and tillage.

Table 2. Cover crop (CC) grazing effect on soil bulk density at subsequent grain crop planting across seven site-years in western and central Kansas

			Bulk density (g/cm^3)		
Region	**Location**	**Treatment**	**2019**	**2020**	**2021**
			0- to 2-inch		
Western	Alexander	Ungrazed CC	1.28a†	-	1.36a
		Grazed CC	1.14a	-	1.36a
	Hays	Ungrazed CC	-	1.25a	1.04a
		Grazed CC	-	1.32a	1.09a
Central	Marquette 1	Ungrazed CC	1.43a	-	1.36a
		Grazed CC	1.23b	-	1.38a
	Marquette 2	Ungrazed CC	-	1.28a	-
		Grazed CC	-	1.32a	-
			2- to 6-inch		
Western	Alexander	Ungrazed CC	1.38a	-	1.44a
		Grazed CC	1.44a	-	1.41a
	Hays	Ungrazed CC	-	1.38a	1.16a
		Grazed CC	-	1.41a	1.13a
Central	Marquette 1	Ungrazed CC	1.54a	-	1.49a
		Grazed CC	1.49a	-	1.53a
	Marquette 2	Ungrazed CC	-	1.48a	-
		Grazed CC	-	1.51a	-

†Means with the same letter within columns are not different ($\alpha = 0.05$) across treatments.

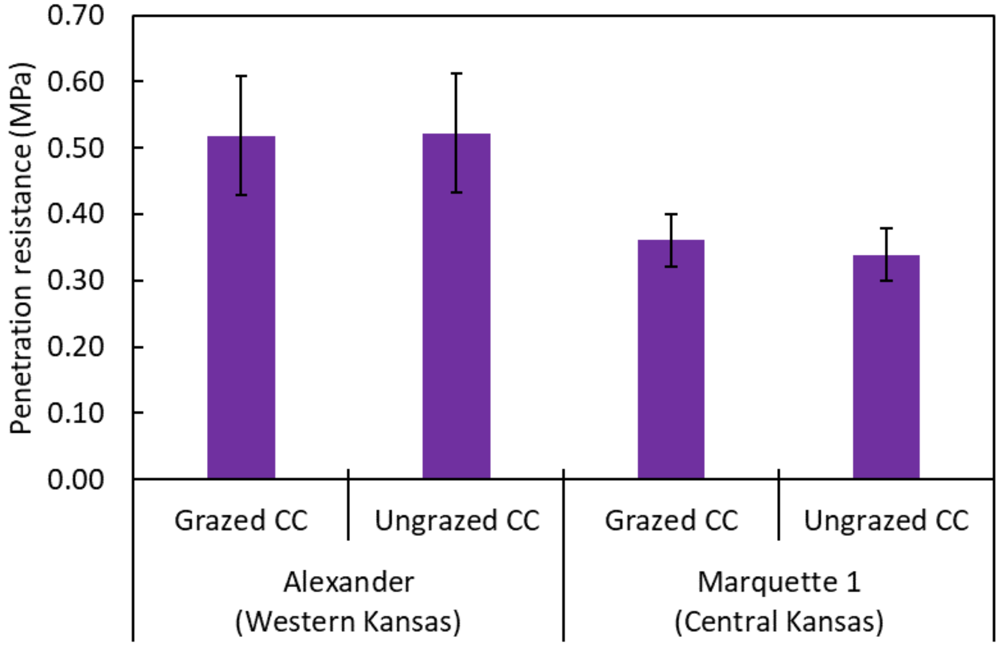

Figure 1. Effect of cover crop grazing on penetration resistance at the 0- to 6-inch soil depth at subsequent grain crop planting at two on-farm sites in 2021. Error bars indicate standard error ($\alpha = 0.05$) and bars with the same letter are not significantly different ($\alpha = 0.05$).