

Cover crop biomass removal rates to optimize livestock production and soil health in no-till dryland cropping systems

Grazing cover crops (CCs) could provide an economic benefit to offset potential lost revenue when grain crop yields are decreased after CCs in dry years. However, there is limited guidance on the optimum biomass removal rate that balances soil health and grazing goals. An on-farm study was established in fall 2022 on a 50-acre producer field in Russell Co., KS to investigate the effects of CC biomass removal rates with cattle grazing on soil health parameters and grain crop yields, and profitability in no-till (NT) dryland cropping systems. The study design was a randomized complete block with three treatments and four replications. The treatments included ungrazed CCs, "talk-half-leave-half" (T-H-L-H, 50% biomass removal), and "graze-out" (G-O, 90% biomass removal). Results showed that T-H-L-H and G-O significantly reduced CC residue amount and height compared to ungrazed CCs but maintained residue cover on the soil surface similar to ungrazed CCs. Cover crop management had no significant effect on soil organic carbon, particulate organic matter, nitrate-N, or P concentrations. However, T-H-L-H somewhat increased soil bulk density compared to ungrazed CCs though both of these were similar to G-O. Soil penetration resistance, wind-erodible fraction, mean weight diameter of water stable aggregates, time-to-runoff, and subsequent grain sorghum yield were unaffected by CC management. These results suggest that farmers and ranchers may be able to graze CCs at greater intensities than T-H-L-H to maximize livestock gains while maintaining soil health, which could increase adoption of CCs. Greater adoption and implementation of cover crops would also benefit water quality protection and improvement efforts in reaching the goals of the approved 9 Element Watershed Restoration And Protection Strategies (WRAPS) Plan developed in partnership with Kansas State University (KSU), Kansas Center for Agriculture Resources and the Environment (KCARE), the Kansas Department of Health (KDHE), and Environment and Environmental Protection Agency (EPA). However, these observations were made in a 1-year study and under exceptional drought conditions, so further investigation will be necessary under conditions of average or above average precipitation when wet soils may be more susceptible to degradation by cattle hoof traffic.

INTRODUCTION

No-tillage (NT) and cover crops (CCs) have been widely recommended to regenerate soils degraded after many years of conventionally-tilled, low-intensity crop production. Soil health benefits of CCs in NT cropping systems include increased soil organic carbon (SOC), enhanced nutrient cycling, reduced compaction, increased water infiltration, and reduced wind and water erosion. However, several barriers to adoption of CCs exist in water-limited regions including the costs of establishing CCs (seed, machinery, labor, and fuel) and the risk of CCs reducing subsequent grain yields due to reduced soil water at next crop planting. Some producers have sought to overcome these barriers by integrating livestock to graze CCs, which has been widely promoted for diversifying agricultural production systems.

Previous research has shown most CC species can provide high-quality forage for livestock, which can extend the grazing season and reduce the need for feeding costly stored forages in concentrated feeding sites for extended periods. Grazing CCs can delay grazing of native rangelands and allow for longer periods of rest and improved rangeland health. Previous research has demonstrated increased system profitability with integrated crop-livestock systems. However, subsequent grain yields have been variable with incidences of reduced yield often having been attributed to soil compaction, aggregate destruction, and reduced water infiltration due to excessive animal hoof traffic. For long-term practitioners of NT, this is a major concern as yield-limiting soil compaction could require tillage for remediation.

At this time, there is limited guidance on the optimum biomass removal rate that balances soil health and grazing goals. Previously, USDA-NRCS has made no provisions for



Figure 1. Temporary electric interior cross fencing was used to limit livestock grazed areas and moved regularly across the plots of the on-farm cover crop grazing intensity study in Russell Co., KS. Photo by Frank Weber.

grazing CCs and current Kansas NRCS recommended stocking rates are based on those developed for native rangelands (T-H-L-H, 50% biomass removal). Previous research suggests that conservative stocking densities that remove 40-50% of biomass do not negatively effects soil properties compared to ungrazed CCs, which suggests that greater levels of biomass removal with grazing could be practical especially when regrowth occurs after grazing and would generate greater profit for farmers and ranchers. However, higher stocking rates (70 to 90% removal) have occasionally resulted in compaction and reduced water infiltration in some studies. The objective of this research is to determine the optimum amount of CC biomass removal with livestock grazing to optimize farm profits and enhancements in soil health on no-till dryland cropping systems in Kansas.

MATERIALS AND METHODS

An on-farm study was established in fall 2022 on a 50-acre producer field in Russell Co., KS ($38^{\circ} 42' 2.2''$ N, $98^{\circ} 37' 58.3''$ W) located in the KSU Kanopolis Reservoir Big Creek Middle Smoky Hill River Watershed Restoration And Protection Strategies (WRAPS) Area to investigate the effects of CC biomass removal

rates with cattle grazing on soil health parameters, grain crop yields, and system profitability in NT dryland cropping systems. Soil types at the study site are the Crete silt loam (72%) and Harney silt loam (28%), and long-term average (30-yr) annual precipitation is 26 in. However, the study period coincided with a period of exceptional drought. The study design was a randomized complete block with three treatments and four replications. Treatments included ungrazed CCs, "tall-half-leave-half" (T-H-L-H, 50% biomass removal), and "graze-out" (G-O, 90% biomass removal).

In fall 2022, a three-species CC mixture of triticale, pea, and rapeseed was planted into wheat stubble about October 1 at 60, 15, and 2 lb/ac, respectively, using a NT drill. No fertilizers were applied. In spring 2023, treatments were established with ungrazed plots of about 1.5 ac and grazed plots of about 5 ac each replicated and randomized across the field. Plots were grazed with yearlings beginning in the last week of April and moved plot-to-plot every 1 to 2 days across the eight grazed plots to achieve desired CC biomass removal rates based on visual assessment (Fig. 1). Plots were only grazed once because of declining apparent forage quality (increasing plant maturity) and limited regrowth because of dry conditions. In May 2023, following the end of grazing but before chemical termination, CC biomass was measured in all plots by hand-clipping, to the ground level, two areas of 2×3 ft per plot. Samples were dried at 122 °F for a minimum of 48 hrs in a forced-air oven and weighed to determine dry matter. Cover crops were chemically terminated in the third week of May, and the whole field was planted to grain sorghum with a NT planter approximately two weeks after termination or about the first week of June. Fertilizer applied to sorghum was based on the standard producer practice and kept consistent across treatments. Grain sorghum was harvested with a field scale combine equipped with a calibrated yield monitor about the last week of October. Plot level yield and moisture content data were extracted using QGIS 3.34 Prizren software, and yields were adjusted to 13.5% moisture content.

At the initiation of the study in fall 2022 before planting CCs, soil samples and water infiltration measurements were collected from the 0-2 and 2-6 in. soil depths for initial characterization of soil chemical and physical properties (Table 1; Fig. 2). Again, in spring 2023, soil samples and water infiltration measurements from ungrazed, T-H-L-H, and G-O plots were collected to determine the effects of biomass removal on soil chemical and physical properties. Soil bulk density (BD) was determined as mass of oven dry soil divided by volume of the core following oven-drying at 221°F for 48 hr. Penetration resistance (PR) was measured at 10 random points within each plot using a hand cone penetrometer (Eijkelkamp Co., Giesbeek, The Netherlands) and readings were divided by the area of the cone (0.31 in.²). Values of penetration resistance were adjusted to a field capacity gravimetric water content of 0.35 (g/g).

Additionally, 10 soil cores were randomly collected within each plot, divided into the 0-2 and 2-6 in. depths, and composited by depth. Samples were air-dried, crushed, and sieved to pass through a 0.08 in. stainless steel screen. The SOC and particulate organic matter (POM, <0.0021 in.) concentrations were determined by loss-on-ignition. Soil pH was determined potentiometrically by an electrode. Soil NO₃-N concentrations in samples were determined with a segmented flow analyzer after extracting the soil with 2 M KCl. Available P was determined

Table 1. Initial soil chemical and physical properties at cover crop planting (study initiation) in fall 2022 near Dubuque, KS.

	SOC [†]	POM	NO ₃ -N	P	BD	MWD	WEF	TTR
Depth	%	%	ppm	ppm	g/cm ³	mm	%	min
0-2 in	2.35 (0.21) [‡]	1.55 (0.26)	28.83 (3.25)	20.13 (1.07)	1.08 (0.09)	1.23 (0.30)	23.74 (1.96)	16.41 (4.05)
2-6 in	1.54 (0.05)	0.45 (0.1)	9.05 (1.19)	9.2 (1.25)	1.42 (0.04)	-	-	-

[†]SOC; soil organic carbon; POM, particulate organic matter; NO₃-N, nitrate-nitrogen; P, phosphorus; BD, bulk density; MWD, mean weight diameter of water stable aggregates; WEF, wind-erodible fraction; TTR, time-to-runoff.

[‡]Numbers in parentheses indicate one standard deviation of the mean.

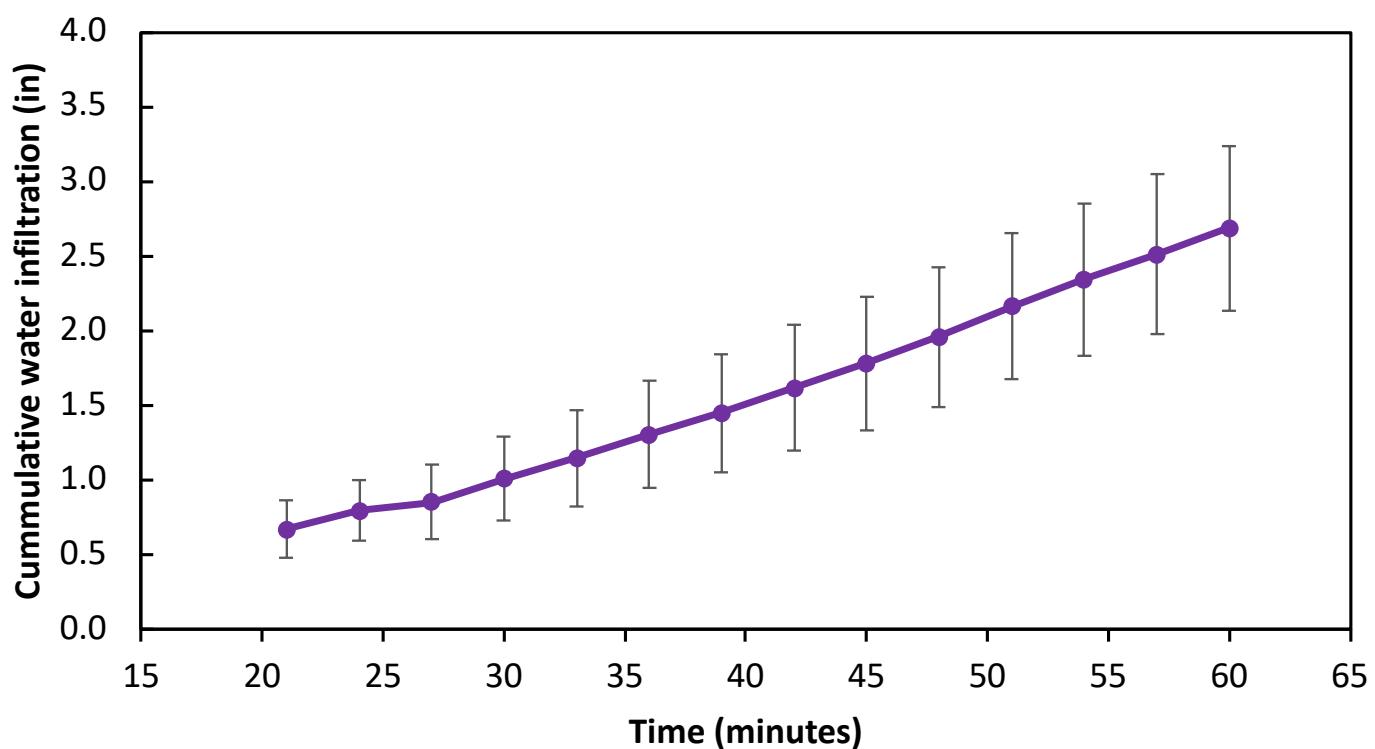


Figure 2. Initial cumulative water infiltration at cover crop planting (study initiation) in fall 2022 near Dubuque, KS.

[†]Error bars indicate standard error of the mean.

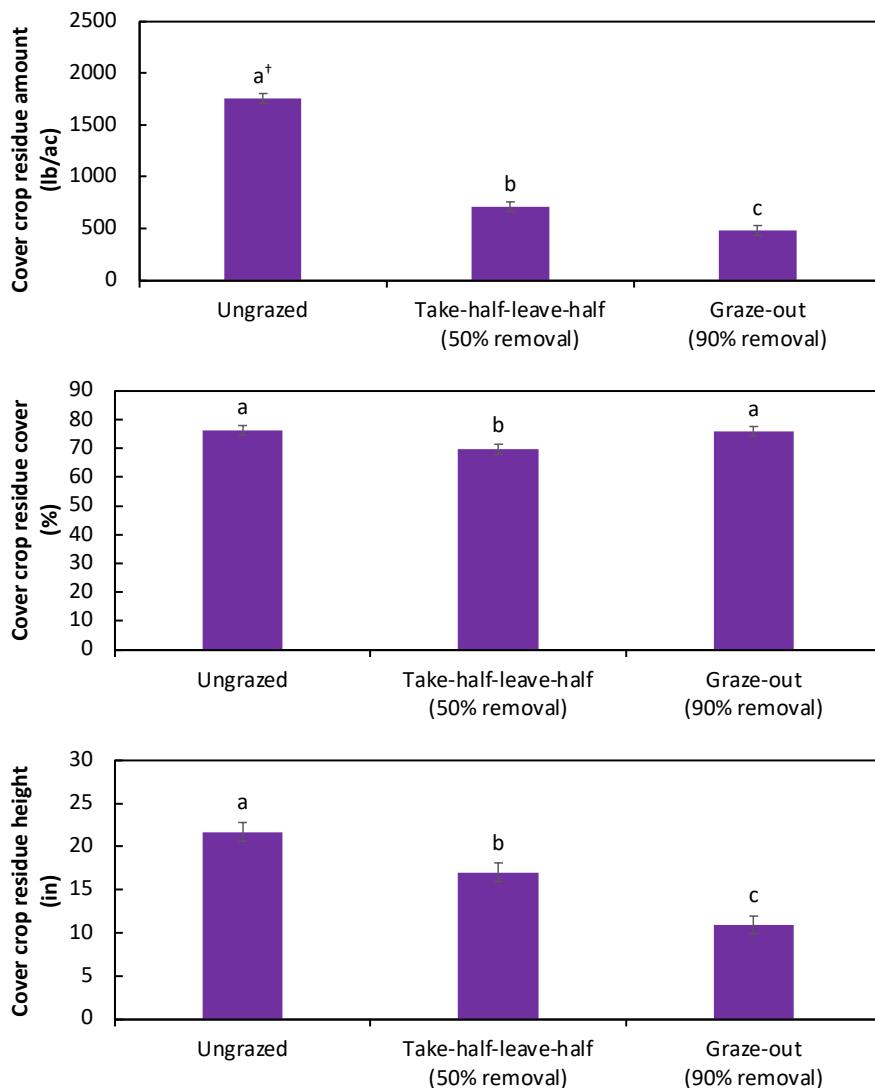


Figure 3. Cover crop residue amount, cover, and height at cover crop termination in spring 2023 near Dubuque, KS.

[†]Bars with the same letter are not significantly different across treatments ($\alpha \leq 0.05$). Error bars indicate standard error of the mean.

by the Mehlich-3 extraction method, and P concentration in the extract was measured using inductively coupled plasma-optical emission spectrometry (ICP-OES). Lastly, intact soils samples were carefully collected with a flat shovel and were allowed to air-dry and then gently passed through a 0.75-in sieve. Subsamples of <0.31-in diameter aggregates were obtained and used to estimate mean weight diameter (MWD) of water stable aggregates by the wet-sieving method. The remaining sample was used to estimate wind-erodible fraction (WEF) (<0.03-in) by the dry-sieving method. Analyses of CC biomass, grain yields, as well as soil chemical and physical properties were performed using the PROC GLIMMIX procedure in SAS ver. 9.4.

RESULTS AND DISCUSSION

Results from this study showed that T-H-L-H and G-O significantly reduced CC residue amount and height compared to ungrazed CCs (Fig. 3; 4) though T-H-L-H maintained greater CC residue amount and height compared to G-O. However, percentage residue cover with G-O was not significantly different from the ungrazed treatment, and T-H-L-H was only somewhat less than G-O and ungrazed CCs (Fig. 3; 4). This suggests that increasing grazing intensity maintained residue cover on the soil surface similar to ungrazed CCs despite reducing residue amount

primarily by reduce residue height. Cover crop management had no significant effect on SOC, POM, NO₃-N, or P concentrations at subsequent grain sorghum planting in spring 2023 (Table 2). These results suggest that increasing grazing intensity maintained soil chemical properties similar to ungrazed CCs. However, SOC, POM, NO₃-N, and P concentrations were greater in the 0-2 in soil depth compared to 2-6 in.

Soil BD was somewhat increased with T-H-L-H and G-O grazing management strategies at subsequent grain sorghum planting compared to study initiation (Table 3). Soil BD was slightly increased with T-H-L-H compared to ungrazed CCs though both of these were similar to G-O. The WEF at subsequent grain sorghum planting was greater in all CC treatments compared to study initiation but was not affected by CC management (Table 3). Cover crop management had no significant effect on PR, MWD, or time-to-runoff (TTR) (Table 3). This suggests that increasing grazing intensity may slightly increase some indicators of soil compaction (i.e., BD) in the months following CCs termination before subsequent cash crop planting. However, increasing grazing intensity maintained indicators of soil erodibility (i.e., MWD and WEF) and water infiltration (i.e., TTR) similar to ungrazed CCs. This was potentially because of exceptional drought conditions during the CC growing season and grazing period that resulted in very dry soils that were less



Figure 4. Cover crop residue remaining after grazing a graze-out (90% removal) plot (left) next to an ungrazed plot (right) divided by temporary electric interior cross fencing in the on-farm cover crop grazing intensity study in Russell Co., KS. Photo by Logan Simon.

Table 2. Cover crop management and sampling depth effects on soil organic carbon (SOC), particulate organic matter (POM), nitrate-nitrogen ($\text{NO}_3\text{-N}$), and phosphorus (P) at subsequent grain sorghum planting in spring 2023 near Dubuque, KS.

Treatment	SOC [†]	POM	$\text{NO}_3\text{-N}$	P
	%	%	ppm	ppm
Management				
Initial	1.94 ^t	1.00	18.9	14.7
Ungrazed CCs	2.11	1.17	13.7	23.5
Take-half-leave-half (50% removal)	1.86	0.91	9.9	20.1
Grazed-out (90% removal)	1.92	1.01	10.7	17.9
Depth				
0-2 in	2.38a	1.56a	21.0a	25.1a
2-6 in	1.54b	0.49b	5.6b	13.0b
Type III test of fixed effects				
Parameter		P-values		
Management (M)	0.3360	0.3956	0.3956	0.3360
Depth (D)	0.0011	0.0006	0.0006	0.0011
M*D	0.7043	0.8675	0.8675	0.7043

[†]Means with the same letter are not significantly different across treatments ($\alpha \leq 0.05$).

Table 3. Cover crop management and sampling depth effects on soil bulk density (BD), penetration resistance (PR), mean weight diameter (MWD) of water stable aggregates, wind-erodible fraction (WEF), and time-to-runoff (TTR) at subsequent grain sorghum planting in spring 2023 near Dubuque, KS.

Treatment	BD	PR	MWD	WEF	TTR
	g/cm ³	MPa	mm	%	min
Management					
Initial	1.25c [†]	-	1.23	23.7b	16.4
Ungrazed CCs	1.26bc	1.04	1.78	33.2a	10.1
Take-half-leave-half (50% removal)	1.33a	1.10	1.75	32.8a	12.1
Grazed-out (90% removal)	1.32ab	0.99	1.90	29.7a	9.0
Depth					
0-2 in	1.16b	1.47a	-	-	-
2-6 in	1.42a	0.61b	-	-	-
Type III test of fixed effects					
Parameter	P-values				
Management (M)	0.0377	0.3309	0.2027	0.0038	0.1654
Depth (D)	0.0009	<0.0001			
M*D	0.1019	0.7822			

[†]Means with the same letter are not significantly different across treatments ($\alpha \leq 0.05$).

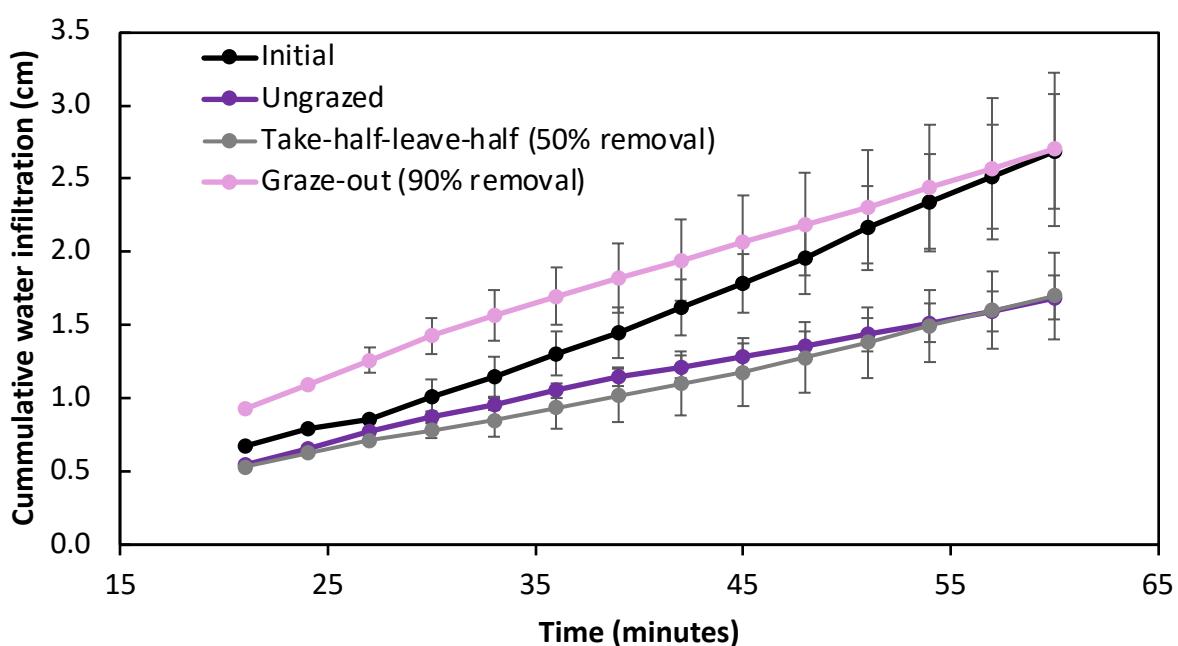


Figure 5. Cover crop management effect on cumulative water infiltration at subsequent grain sorghum plating in spring 2023 near Dubuque, KS.

[†]Error bars indicate standard error of the mean.

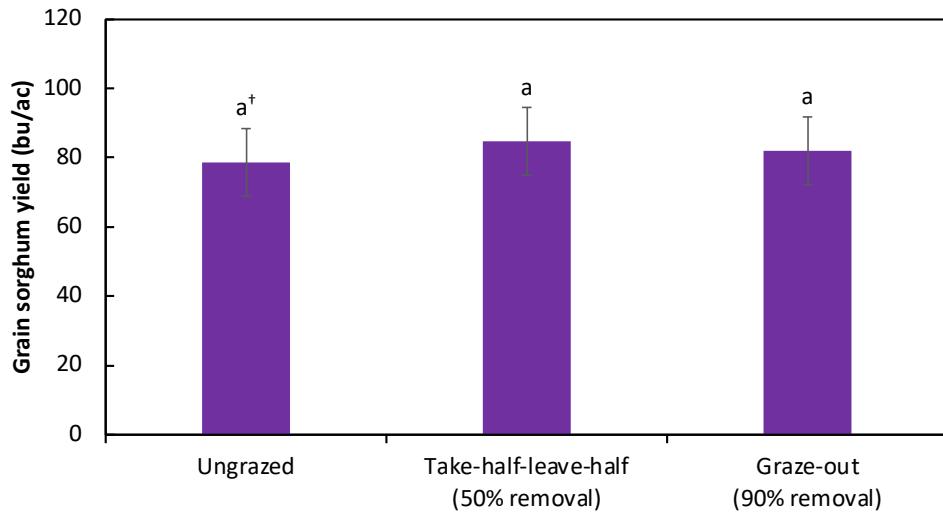


Figure 6. Cover crop management effect on subsequent grain sorghum yields in fall 2023 near Dubuque, KS.

[†]Bars with the same letter are not significantly different across treatments ($\alpha \leq 0.05$). Error bars indicate standard error of the mean.

susceptible to degradation by cattle hoof traffic.

Cover crops treatments had somewhat less cumulative water infiltration compared to study initiation up to approximately 40 minutes, but G-O reached cumulative water infiltration similar to study initiation after 40 minutes and up to 60 minutes (Fig. 5). After approximately 30 minutes, T-H-L-H and ungrazed CCs had less cumulative water infiltration compared to G-O or study initiation. This suggests that increasing grazing intensity maintained or increased cumulative water infiltration compared to ungrazed CCs. Results showed no significant effect of CC management on subsequent grain sorghum yield (Fig. 6), which suggests that increasing grazing intensity maintained similar subsequent cash crop yields to ungrazed CCs.

CONCLUSION

Results showed that T-H-L-H and G-O CC grazing strategies significantly reduced CC residue amount and height compared to ungrazed CCs but maintained residue cover on the soil surface similar to ungrazed CCs. Cover crop management had

no significant effect on SOC, POM, NO₃-N, or P concentrations, but T-H-L-H somewhat increased soil BD compared to ungrazed CCs though both of these were similar to G-O. Soil PR, WEF, MWD, TTR, and subsequent grain sorghum yield were unaffected by CC management. These results suggest that increasing grazing intensity maintained soil health indicators and subsequent grain crop yields similar to ungrazed CCs. These results suggest that farmers and ranchers may be able to graze CCs at greater intensities than T-H-L-H to maximize livestock gains while maintaining soil health, which could increase adoption of CCs. Greater adoption and implementation of cover crops would also benefit water quality protection and improvement efforts in reaching the goals of the approved 9 Element WRAPS Plan developed in partnership with KSU, KCARE, KDHE, and EPA. Nevertheless, these observations were made in a 1-year study and under exceptional drought conditions, so further investigation will be necessary under conditions of average or above average precipitation when wet soils may be more susceptible to degradation by cattle hoof traffic.

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