

Long-Term Cover Crop Management Effects on Soil Health in Semiarid Dryland Cropping Systems

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Summary

Growing cover crops (CC) in semiarid drylands may provide benefits to soil health. This study examined long-term CC management effects in a no-till winter wheat-grain sorghum-fallow cropping system in southwest Kansas. Objectives were to assess the impacts of CCs on 1) soil organic carbon (SOC) and nitrogen (N) stocks, 2) soil susceptibility to erosion, as well as to 3) quantify the effects of haying cover crops as annual forages. Treatments were spring-planted and included peas for grain as well as one-, three-, and six-species CC mixtures of oats, triticale, peas, buckwheat, turnips, and radishes compared with conventional chemical-fallow. Half of each CC treatment was harvested for forage. All phases of each rotation were present every year. Soil samples were collected from the 0- to 6-inch depth in 2018 and 2019 corresponding with wheat planting and harvest in the three-year rotation. Results indicate no significant difference in SOC with CCs compared to fallow in either 2018 or 2019, though SOC stocks were greater than in 2012. This was possibly due to periods of drought reducing total carbon (C) inputs compared to earlier periods of relatively greater precipitation. Haying of CCs had no effect on soil health indicators compared to when CCs were left standing. Soil N was not increased with CCs compared to fallow or peas. Mean weight diameter of wet aggregates in 2018 was not different between CCs hayed (0.042 in.) and CCs left standing (0.044 in.) but was greater than fallow (0.033 in.) or peas (0.030 in.). Growing a CC significantly increased the proportion of larger (0.30- to 0.08-in.) aggregates (37%) compared to peas (21%) but not compared to fallow (24%). These differences were not significant after wheat harvest in 2019. Our findings suggest that CCs may improve soil physical properties compared to conventional chem-fallow in semiarid dryland cropping systems.

Introduction

Growing cover crops (CCs) in semiarid dryland cropping systems in the central Great Plains (CGP) has potential to provide several benefits to soil health in the region. These include reduced susceptibility to soil erosion as well as improved nutrient cycling. However, even with these potential benefits and an increasing interest among CGP crop producers, CC adoption has been slow in the region. This is mostly due to the fact that CCs may deplete vital soil water, which results in reduced yields of subsequent cash crops compared to chemically-controlled summer-fallow, where herbicides are used to manage weed growth to store soil moisture for the next crop. Past research efforts

in southwest Kansas have shown that replacement of fallow with CCs or forage crops resulted in increased soil organic matter (SOM) content and stability of wet soil aggregates, as well as reduced soil wind-erodible fraction and runoff. These results suggest that CCs in semiarid regions have the potential to improve soil health similarly to those reported in more humid regions, at least in the short term (<10 years), despite limited rainfall and high evaporative demand. However, information is lacking regarding the long-term (>10 years) soil health effects of integrating cover crops in dryland cropping systems.

Increased adoption of CCs by dryland producers in the semiarid CGP can enhance residue cover to reduce the susceptibility of the soil to erosion. Reducing erosion is particularly important in semiarid dryland crop production systems where residue levels are often low, and fallow fields are left exposed. Grazing and/or haying of CCs for forage can provide an economic benefit to offset potential lost revenue associated with decreased crop yields when CCs are grown ahead of a cash crop in dry years. However, there is concern that harvesting CCs as forages and the resulting reduction in residue left on the soil surface may negate the beneficial effects of CCs for soil conservation. Our objectives were to assess the long-term impacts of CCs on 1) soil organic carbon (SOC) and nitrogen (N) stocks, 2) soil susceptibility to erosion, as well as to 3) quantify the effects of haying CCs as annual forages upon soil health.

Procedures

This study was conducted in a long-term experiment of fallow replacement (cover crops, forage crops, and grain crops) established in 2007 at the Kansas State University Southwest Research-Extension Center near Garden City, KS. The soil is a Ulysses silt loam with 1 to 3% slope. The study design was a split-split-plot randomized complete block with four replications. Crop phase was the main plot, crop species or mixture was the split plot, and termination method (cover, forage, or grain) was the split-split plot. Cover crops included a triticale monoculture, a three-species mixture of oats/triticale/pea, and a six-species cocktail mixture of oats/triticale/pea/buckwheat/turnip/radish. Cover crop plots were split with half of each plot harvested for forage. Additionally, peas were grown and harvested for grain. Treatments with spring-planted crops grown in place of fallow were compared with the conventional winter wheat-grain sorghum-fallow cropping system for a total of 8 treatments. All phases of each crop rotation were present every year.

Soil sampling occurred before wheat planting in fall 2018 and after wheat harvest in summer 2019. Soil cores were taken from the 0- to 2-, 2- to 6-, and 6- to 12-inch depths for determination of bulk density as well as SOC and inorganic nitrogen (NO_3 and NH_4) stocks. Briefly, the samples taken at each depth were dried at 220°F for 48 hours, and bulk density was determined by mass of oven-dry soil divided by the volume of the core. Subsamples from each depth were air-dried and ground to pass through a 0.08-in. sieve. Soil nitrate-N ($\text{NO}_3\text{-N}$) and ammonium-N ($\text{NH}_4\text{-N}$) concentrations in samples were determined colorimetrically after the soil samples were extracted with 2 M KCl. A portion of the samples were ground with a mortar and pestle to pass through a 0.01 in. sieve, and SOC concentration was determined by dry combustion using a CN analyzer after pretreating samples with 10% (v/v) HCl to remove carbonates. Additional samples collected from the 0- to 2-in. soil depth with a flat shovel were air-dried

and passed through sieves with 0.185- to 0.30-in. mesh to obtain air-dry aggregates of 0.185- to 0.30-in. diameter. These samples were used to estimate water-stable aggregates by the wet-sieving method. A sand correction was done for each aggregate size fraction, and the data were used to compute the aggregate size distribution and mean weight diameter (MWD) of water-stable aggregates. Monthly precipitation data (Table 1) over the study period were obtained from the Mesonet station located about 500 ft from the experiment. Statistical analysis was completed in SAS using PROC GLIMMIX in SAS v. 9.4 (SAS Inst. Inc., Cary, NC) to assess differences among management scenarios.

Results

Soil Organic Carbon and Nitrogen Stocks

Treatments of differing CC species diversity were not significantly different for any observed soil health parameter. Soil organic carbon stocks (Table 2) in 2018 and 2019 showed no significant differences compared to fallow but were greater than SOC values determined in 2012 (Blanco-Canqui et al., 2013). This suggests SOC gains made with CCs in semiarid environments may not persist during sustained periods of drought (Table 1) that reduce total carbon inputs from lower CC biomass as well as wheat and grain sorghum yields that result under very dry conditions. Cover crops did not increase soil N (Table 3) compared to peas or fallow. However, recommended rates of N were applied to both wheat and sorghum crops and may have masked any potential differences. Soil N stocks were lower in 2019 following winter wheat harvest.

Bulk Density and Water-Stable Aggregates

Soil bulk density (BD), a common measurement of soil compaction, was decreased with CCs (1.42 g/cm³) compared to fallow (1.48 g/cm³) (Table 2) but was similar to grain pea (1.39 g/cm³) in fall 2018. No difference in soil bulk density was determined across treatments following winter wheat harvest in 2019. Water-stable aggregates are measured as an indicator of soil susceptibility to erosion. Larger aggregates are less susceptible to erosive forces. In 2018, the proportion of larger (0.08–0.30 in.) aggregate size fractions was increased with CCs (37%) compared to peas (21%) but was similar to fallow (24%) (Table 5). The proportion of smaller (0.01–0.04 in.) aggregates was decreased with CCs (32%) compared to fallow (45%) but was similar to peas (41%). Results were not significant in 2019 following winter wheat harvest. Mean weight diameter of wet aggregates in 2018 (Table 4) was not different when CCs were left standing (0.044 in.) versus when they were hayed as an annual forage (0.042 in.), but both were greater than fallow (0.033 in.) or peas (0.030 in.). Differences were not significant in 2019. Results suggest that intensification of cropping systems with CCs in place of fallow under no-till management may be a means of improving soil physical properties in semiarid drylands.

Reference

- Blanco-Canqui, H., J.D. Holman, A.J. Schlegel, J. Tatarko, and T.M. Shaver. 2013. Replacing fallow with cover crops in a semiarid soil: effects on soil properties. *Soil Sci. Soc. Am. J.* 77:1026–1034. doi:10.2136/sssaj2013.01.0006.

Table 1. Monthly precipitation from 2007 to 2019 at Garden City, KS

Month	Precipitation													30-yr avg.†
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	
	-----Inches-----													
Jan.	0.6	0.3	0.1	0.7	0.2	0.0	0.3	0.0	0.5	0.0	1.5	0.0	0.3	0.5
Feb.	0.6	0.6	0.1	0.4	0.4	0.8	0.2	0.0	0.3	0.3	0.0	0.0	0.8	0.6
Mar.	1.8	0.3	1.1	1.8	0.7	1.9	0.1	0.1	0.3	0.0	2.8	0.4	2.1	1.3
Apr.	2.9	1.7	4.4	2.2	1.8	1.6	0.3	0.5	0.4	4.7	4.4	0.8	0.1	1.7
May	1.2	1.9	1.9	3.9	1.1	0.3	1.0	0.6	6.3	1.1	1.1	2.2	5.9	3.0
Jun.	2.5	3.1	3.7	1.4	1.7	1.2	1.6	9.4	1.4	4.0	1.1	3.9	1.1	3.1
Jul.	1.7	1.2	3.1	1.3	0.55	1.9	3.0	3.0	4.9	5.8	2.1	8.6	1.9	2.8
Aug.	2.6	2.5	2.2	2.7	2.4	1.0	3.4	1.8	2.9	1.8	2.3	1.8	1.4	2.5
Sept.	2.1	0.7	1.6	0.3	0.35	1.1	1.5	2.5	0.0	0.1	3.2	1.9	0.1	1.4
Oct.	0.2	4.7	3.0	0.7	0.4	0.9	0.8	1.6	2.5	0.0	1.9	3.6	0.4	1.2
Nov.	0.1	0.4	0.4	0.1	0.4	0.0	0.7	0.0	0.9	0.1	0.0	0.3	0.2	0.6
Dec.	1.3	0.0	0.2	0.1	2.0	0.5	0.1	0.2	1.1	0.2	0.0	1.6	1.2	0.6
Annual	17.6	17.3	21.7	15.7	12.1	10.9	12.9	19.6	21.5	18.1	20.3	25.0	15.5	19.24

†30-year averages are for the period 1981-2010.

Table 2. Cover crop management effect on bulk density (BD) and soil organic carbon (SOC) stocks in the 0- to 6-inch soil depth in spring 2012, fall 2018, and summer 2019

Treatment	Spring 2012		Fall 2018		Summer 2019	
	BD	SOC	BD	SOC	BD	SOC
	g/cm ³	tons/acre	g/cm ³	tons/acre	g/cm ³	tons/acre
Fallow	1.49 a†	8.33 a	1.48 a	9.36 a	1.39 a	8.71 a
Pea (grain)	1.40 a	9.20 ab	1.39 b	9.61 a	1.39 a	9.19 a
Cover crops (standing)	1.47 a	9.29 b	1.41 b	9.80 a	1.39 a	8.73 a
Cover crops (hayed)	1.45 a	8.85 ab	1.43 ab	9.79 a	1.40 a	9.10 a

†Means with the same lower-case letter within the same column are not significantly different among management scenarios.

Table 3. Effect of cover crop management on soil nitrogen (NO₃-N and NH₄-N) stocks in the 0- to 6-inch soil depth in fall 2018 and summer 2019

Treatment	Fall 2018		Summer 2019	
	NO ₃ -N	NH ₄ -N	NO ₃ -N	NH ₄ -N
	----- lb/a -----			
Fallow	31.82 a†	3.73 a	7.89 a	0.15 a
Pea (grain)	39.42 a	4.90 a	9.41 a	1.71 a
Cover crops (standing)	38.04 a	4.47 a	9.22 a	1.86 a
Cover crops (hayed)	34.44 a	4.56 a	9.43 a	1.77 a

†Means with the same lower-case letter within the same column are not significantly different among management scenarios.

Table 4. Effect of cover crop management on mean weight diameter (MWD) of wet aggregates from the 0- to 2-inch soil depth in fall 2018 and summer 2019

Treatment	Fall 2018	Summer 2019
	MWD	
	----- Inches -----	
Fallow	0.033 ab†	0.082 a
Pea (grain)	0.030 b	0.070 a
Cover crops (standing)	0.044 a	0.090 a
Cover crops (hayed)	0.042 ab	0.080 a

†Means with the same lower-case letter within the same column are not significantly different among management scenarios.

Table 5. Cover crop management effect on wet aggregate size distribution for the 0- to 2-inch soil depth in fall 2018 and summer 2019

Sample period	Treatment	< 0.01-in.	0.01- to 0.04-in.	0.04- to 0.08-in.	0.08- to 0.30-in.
		----- Percent of each size fraction -----			
Fall 2018	Fallow	23 a†	45 a	8 a	24 ab
	Pea (grain)	30 a	41 ab	8 a	21 b
	Cover crops (standing)	26 a	32 b	6 a	37 a
	Cover crops (hayed)	23 a	33 ab	7 a	37 a
Summer 2019	Fallow	20 a	35 a	12 a	33 a
	Pea (grain)	21 a	39 a	13 a	26 a
	Cover crops (standing)	24 a	30 a	8 ab	39 a
	Cover crops (hayed)	23 a	38 a	4 a	34 a

†Means with the same lower-case letter within the same column and sample period are not significantly different among management scenarios.