Near-Surface Soil Property Responses to Perennial Forages in a Semiarid Region

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RATIONALE AND OBJECTIVE

Perennial forages can serve to enhance near-surface soil properties, yet there is limited information regarding soil responses to different perennial crop types and phase lengths in semiarid regions.

This study was conducted to evaluate effects of five perennial forages and annual cropping on near-surface soil properties in south-central North Dakota.

METHODS

Site Description

- Location: USDA-ARS Northern Great Plains Research Laboratory, approximately 1 km southwest of Mandan, ND USA (46°46’ N, -100°55’ W).
- Climate: Semiarid continental climate (MAT, 4°C; MAP, 410 mm).
- Soil/Topography: Parshall fine sandy loam (coarse-loamy, mixed, superactive, frigid Pachic Haplustoll), 0-2% slope.
- History: Forage nursery.

Treatment Description

- Forages/Crop: Five perennial forages [alfalfa (*Medicago* spp.), intermediate wheatgrass (*Thinopyrum intermedium* (Host) Barkw. & D.R. Dewey subsp. *intermedium*), switchgrass (*Panicum virgatum* L.), intermediate wheatgrass-alfalfa mixture, switchgrass-alfalfa mixture] and annual cropping [spring wheat (*Triticum aestivum* L.)] were evaluated for their effects on near-surface soil properties.
- Phases: Treatments were initiated in 2006. Beginning in 2008 and continuing through 2011, perennial forage treatments in one-fourth of each plot were killed with herbicides in fall and seeded to spring wheat the subsequent spring. Accordingly, each perennial forage treatment was present in phases ranging from 2-5 years (Fig. 1).
- Plot Size/Replication: Forage strips, 9.1 m x 37 m. Individual crop plots, 9.1 m x 9.1 m. Treatments replicated four times.

Sample Collection, Processing, and Analyses

- Collection: Spring soil samples collected in 2008-2011 in plots converted to wheat production from 0-30 cm at depths of 0-5, 5-10, 10-20, 20-30 cm (composited 8 cores/depth). Separate sample for soil aggregates collected from 0-15 cm.
- Processing and Laboratory Analyses: 0-30 cm samples air dried, hand sieved (2 mm), and analyzed for soil pH, particulate organic matter (POM) C and N, soil organic C, and total N. Results expressed on a volumetric basis using field-measured soil bulk density. 0-15 cm samples air-dried, sieved to collect 1-2 mm aggregate fraction, and analyzed for water stability using wet sieving.
- Data Analyses: Soil property responses within years were evaluated using PROC MIXED in SAS at P≤0.05.

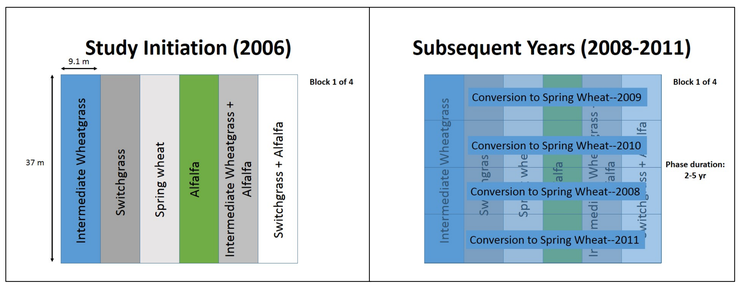

Figure 1. Forage and conversion strips, 2006 and 2008-2011.

FINDINGS

P-Value Summary

Property / Depth(cm)	P-value			
Soil bulk density	**2008**	**2009**	**2010**	**2011**
0-5	0.3534	0.1270	0.3567	***0.0187***
5-10	0.2347	0.7890	***0.0006***	***0.0039***
Soil pH				
0-5	0.1712	0.0926	***0.0264***	***0.0116***
5-10	0.3404	0.2211	0.1462	0.1462
POM-C				
0-5	0.1269	0.1812	0.3416	0.2282
5-10	0.5201	0.3599	***0.0157***	***0.0050***
POM-N				
0-5	0.2345	0.0996	0.6396	0.3921
5-10	0.4209	0.2961	0.1305	***0.0115***
SOC:TN				
0-5	0.2763	0.0785	0.0559	***0.0300***
5-10	0.7349	0.6347	0.8757	0.1947

- Treatment effects were not observed below 10 cm in any year, nor did soil organic C or total N respond to treatment (data not shown).
- Measured soil properties varied among treatments only in 2010 and 2011, corresponding to phase lengths of four and five years, respectively.
- Soil bulk density was most sensitive to treatment, followed by soil pH and POM-C, then POM-N and SOC:TN ratio.
- **Phase lengths of 4-5 years were required for perennial forages to affect soil properties in near-surface (0-10 cm) depths.**

Treatment Means

Year	Soil property	Spring wheat	Alfalfa	Interm. wheatgrass	Interm. wheatgrass + Alfalfa	Switchgrass	Switchgrass + Alfalfa
		0-5 cm					
2010	Soil pH (-log[H$^+$])	5.51 (0.14) b†	6.10 (0.42) a	6.01 (0.19) a	6.20 (0.10) a	5.91 (0.25) a	5.87 (0.14) ab
2011	Soil pH (-log[H$^+$])	5.71 (0.14) b	6.48 (0.34) a	6.20 (0.08) a	6.67 (0.18) a	6.26 (0.31) a	6.24 (0.20) a
	Soil bulk density (Mg m^{-3})	1.46 (0.01) ab	1.49 (0.01) a	1.39 (0.03) c	1.38 (0.03) c	1.41 (0.01) bc	1.43 (0.01) abc
	SOC:TN	10.2 (0.3) a	9.4 (0.2) c	10.2 (0.2) a	10.1 (0.1) ab	10.2 (0.2) a	9.6 (0.2) bc
		5-10 cm					
2010	Soil bulk density (Mg m^{-3})	1.58 (0.01) a	1.54 (0.02) ab	1.48 (0.01) c	1.51 (0.02) bc	1.48 (0.02) c	1.50 (0.02) c
	POM-C (kg C ha^{-1})	961 (197) b	858 (125) b	1501 (120) a	1156 (180) b	1049 (170) b	999 (241) b
2011	Soil bulk density (Mg m^{-3})	1.57 (0.02) a	1.54 (0.02) ab	1.49 (0.02) b	1.51 (0.03) b	1.46 (0.01) c	1.48 (0.01) b
	POM-C (kg C ha^{-1})	240 (60) b	368 (134) b	537 (135) b	929 (158) a	436 (56) b	316 (90) b
	POM-N (kg N ha^{-1})	101 (5) b	117 (4) ab	109 (9) b	133 (8) a	96 (3) b	113 (7) b

† Values in parentheses reflect standard error of the mean. Values in a row with unlike letters differ (P≤0.05).

- Perennial forages mitigated soil acidification at 0-5 cm, while intermediate wheatgrass, switchgrass, and alfalfa-grass mixtures contributed to lower soil bulk density compared to alfalfa and spring wheat.
- Intermediate wheatgrass and the intermediate wheatgrass-alfalfa mixture enhanced POM C and N compared to other perennial forages or spring wheat.
- Water-stable aggregates increased under grass-alfalfa mixtures compared to alfalfa, switchgrass, and spring wheat (Fig. 2).
- **Intermediate wheatgrass and intermediate wheatgrass + alfalfa were most effective at mitigating soil acidification and compaction, while enhancing aggregate stability and moderately-labile organic matter.**

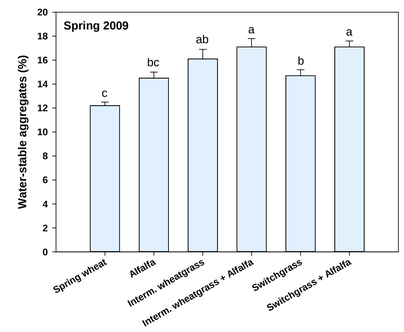

Figure 2. Treatment effects on water-aggregate stability, 2009.

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