Soil Quality Responses to Contrasting Management

Observations from Long-term Trials in Central North Dakota

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NEED FOR RESEARCH

Increased emphasis has been placed on developing conservation management practices that are inherently resilient to external stressors, yet are highly productive, economically competitive, and environmentally benign. This nexus of *productivity, profitability,* and *ecosystem health* has underscored the critical role of soil to affect agricultural and environmental outcomes through impacts on ecosystem services. Accordingly, comprehensive evaluations of soil quality, and its trajectory over time, are necessary to assess the sustainability of conservation management practices.

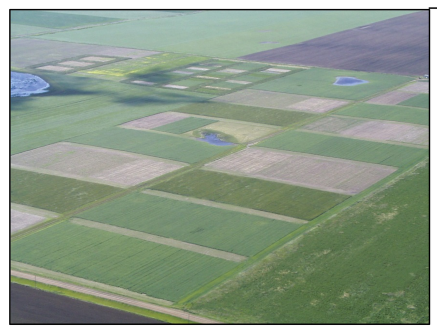
APPROACH

Field sites were located at the USDA-ARS Northern Great Plains Research Laboratory near Mandan, ND USA (46° 46′ N, 100° 55′ W). Contrasting **Conservation Agriculture (CA)** and **Business as Usual (BAU)** treatments were selected from four long-term cropping system studies on the same soil type (Temvik-Wilton silt loam).

- Near-surface (0-5 cm) and whole profile (0-120 cm) soil samples were collected from each treatment in May 2014.
- A suite of soil physical, chemical, and biological measurements were conducted following established methods.
- To assess treatment effects on integrative measures of soil quality, values for select near-surface soil properties were used to calculate two soil quality indices: Soil Management Assessment Framework (SMAF) and the Haney Soil Health Test. Multi-year grain yields for predominant crops were determined for contrasted treatments.
- Treatment effects on raw and scored data were evaluated by ANOVA using PROC mixed in SAS (P≤0.05).

TREATMENTS

CONTRAST 1 ⟶ *Crop Diversity/Intensity*



Long-term Crop Diversity Study (est. 1984)
- CA = Five year crop rotation
- BAU = Small grain - fallow

CONTRAST 2 ⟶ *Livestock Integration*

Integrated Crop-Livestock Study (est. 1999)
- CA = Three year rotation, winter grazing
- BAU = Three year rotation, no grazing, residue removed

CONTRAST 3 ⟶ *Crop Diversity/Cover Crop*

Soil Quality Management Study (est. 1993)
- CA = Spring wheat - Corn - Cover Crop
- BAU = Continuous spring wheat, residue removed

CONTRAST 4 ⟶ *Fall-Seeded Cover Crop*

Bioenergy Cropping Systems Study (est. 2009)
- CA = Spring wheat - Dry pea/Cover Crop
- BAU = Spring wheat - Dry pea

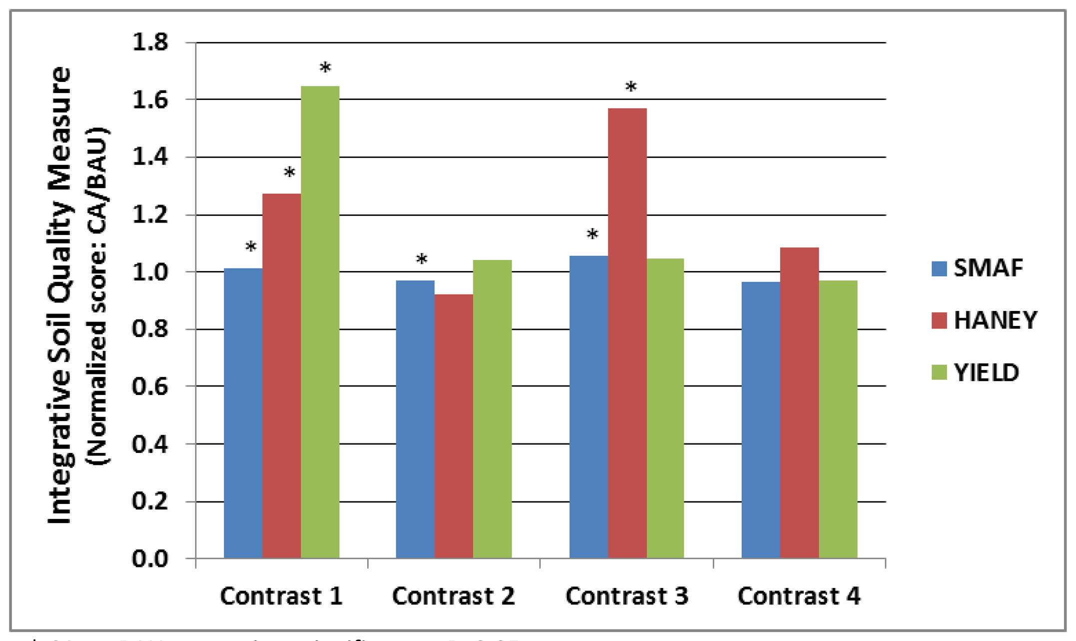
FINDINGS

	CONTRAST 1 Crop Diversity/Intensity			CONTRAST 2 Livestock Integration			CONTRAST 3 Crop Diversity/Cover Crop			CONTRAST 4 Fall-Seeded Cover Crop		
Category/Soil Property (0-5 cm)	**CA**	**BAU**	**P-value**	**CA**	**BAU**	**P-value**	**CA**	**BAU**	**P-value**	**CA**	**BAU**	**P-value**
Physical												
Soil bulk density (Mg m^{-3})	1.06 (0.03)†	1.22 (0.02)	***0.0102***	1.10 (0.06)	1.08 (0.02)	*0.7621*	1.17 (0.01)	1.10 (0.03)	*0.0610*	1.14 (0.03)	1.06 (0.03)	***0.0122***
Water holding capacity (m^3 m^{-3})	0.19 (0.01)	0.16 (0.01)	***0.0014***	0.19 (0.01)	0.19 (0.01)	*0.8353*	0.17 (0.01)	0.17 (0.01)	*0.8159*	0.18 (0.01)	0.20 (0.01)	***0.0144***
Water-stable aggregates (%)	46 (5)	35 (2)	*0.0504*	68 (5)	74 (3)	*0.0748*	42 (5)	41 (4)	*0.8963*	61 (4)	68 (2)	*0.0863*
Sorptivity (cm $s^{-1/2}$)	0.16 (0.02)	0.06 (0.01)	***0.0067***	0.14 (0.02)	0.17 (0.03)	*0.3777*	0.12 (0.04)	0.13 (0.02)	*0.5176*	0.14 (0.03)	0.21 (0.08)	*0.4706*
Chemical												
Soil pH (-log[H^+])	5.0 (0.1)	5.8 (0.1)	***0.0024***	6.0 (0.1)	6.5 (0.1)	***0.0070***	5.9 (0.1)	5.3 (0.2)	***0.0188***	6.1 (0.2)	5.9 (0.1)	*0.3189*
Amino N (kg N ha^{-1})	93 (6)	71 (4)	***0.0069***	178 (12)	118 (7)	***0.0055***	90 (3)	130 (1)	***0.0011***	122 (16)	123 (5)	*0.9439*
Soil organic C (Mg C ha^{-1})	15.6 (0.4)	13.1 (0.1)	***0.0012***	17.1 (0.8)	18.9 (0.5)	*0.1182*	13.5 (0.6)	13.7 (0.7)	*0.7799*	15.8 (0.6)	15.6 (0.5)	*0.8816*
POM C (Mg C ha^{-1})	4.1 (0.2)	1.9 (0.2)	***0.0032***	13.8 (0.8)	5.4 (1.0)	***0.0225***	2.1 (0.1)	3.8 (0.7)	*0.1071*	3.4 (0.6)	3.9 (0.6)	*0.4974*
Biological												
Microbial biomass C (mg C kg^{-1})	428 (14)	507 (13)	***0.0065***	899 (73)	733 (62)	*0.0584*	667 (36)	684 (44)	*0.7834*	1150 (50)	1172 (36)	*0.5789*
Urease activity (μg NH_4 g^{-1} soil 2 h^{-1})	44 (2)	75 (10)	***0.0495***	182 (13)	182 (6)	*0.9689*	69 (30)	47 (12)	*0.5358*	83 (7)	99 (14)	*0.2588*
Phosphodiesterase (μg PN g^{-1} soil h^{-1})	14 (3)	28 (3)	***0.0330***	113 (18)	129 (19)	*0.0756*	36 (8)	14 (4)	*0.0736*	58 (3)	98 (28)	*0.2223*
ß-Glucosidase (μg PN g^{-1} soil h^{-1})	188 (27)	255 (15)	*0.0545*	638 (116)	506 (5)	*0.3210*	364 (15)	260 (3)	***0.0024***	272 (42)	406 (51)	*0.1378*
Bacteria (nmol FAME g^{-1} soil)	91 (6)	97 (2)	*0.3741*	168 (14)	95 (7)	***0.0158***	92 (4)	84 (1)	*0.1339*	87 (8)	106 (14)	*0.0603*
Fungi (nmol FAME g^{-1} soil)	57 (6)	80 (9)	*0.0686*	112 (18)	73 (2)	*0.1067*	63 (3)	42 (3)	***0.0127***	59 (4)	72 (6)	*0.0821*

† Values in parentheses reflect the standard error of the mean.

- Increased crop diversity/intensity contributed to improved soil physical condition, as well as greater amino N, soil organic C, and POM C. Conversely, soil biological attributes were not enhanced by increased crop diversity/intensity. • Livestock integration increased amino N, POM C, and total bacteria. • Increased crop diversity/intensity and livestock integration contributed to greater soil acidification. • Inclusion of cover crops coupled with increased crop diversity contributed to less soil acidification and greater ß-glucosidase activity (involved in C cycling) and total fungi, but lower amino N. • Soil quality responses to fall-seeded cover crops were subtle.

Outcomes from this evaluation suggest the sustainability of dryland cropping systems can be improved through the application of conservation management practices that emphasize increased crop diversity.



* CA vs. BAU comparison significant at P≤0.05.

- Increased crop diversity/ intensity and inclusion of cover crops with increased crop diversity possessed greater SMAF and/or Haney scores. • Grain yield was greater with increased crop diversity/intensity, and did not differ between other contrasted treatments.

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