Soil Quality Indicators among Different Farming Systems

Abstract

Soil samples were collected in summer 2009 at 11 different farm "pods" in different areas of Iowa, each pod containing fields and pastures with different management practices. Perennial vegetation resulted in significantly higher total soil carbon and stable aggregate content. Continuously grazed pastures had significantly higher carbon content in the surface six inches and significantly higher stable aggregate content than rotationally grazed pastures.

Cooperators

Francis Thicke, Fairfield
Bruce Carney, Maxwell
Dan Specht, McGregor
Dan and Torray Wilson, Paullina
Greg Koether, Giard
Linda Grice, South English
Paul Mugge, Sutherland
Ron Rosmann, Harlan
Ryan Herman, New Albin
Tom Frantzen, New Hampton
Tom German, Holstein

Project Timeline

2009–2011 (Year 1 Report)

Web Link

www.practicalfarmers.org

Contact

Kevin Dietzel, 515.232.5661
kevin@practicalfarmers.org

Funding

ISU College of Agriculture and Life Sciences On-Farm Research and Demonstration, Walton Family Foundation

Background

During Iowa's spring 2008 floods, PFI members who had grass-based livestock systems and long crop rotations reported their soils held the rainwater better and eroded less than surrounding fields. This experiment was designed to test those claims. The main objective of the experiment was to quantify the ecological resiliency of different farming systems by measuring water infiltration rates (reported separately) and soil quality indicators including total soil carbon, bulk density and stable aggregate content (SAC) in various farming systems.

Initial data from research conducted at the Neal Smith Wildlife Refuge shows that agricultural landscapes need to be redesigned to include at least 10% to 20% continuous living cover. This amount of cover avoided a 7 T/A loss of soil during the spring 2008 floods as compared to systems with no cover (Personal Communication, Matthew Helmers, 2009).

Quantitative measurement of soil loss from farm fields or pastures is difficult and expensive to do, so we chose to measure select indicators of soil health. SAC is an indicator of a healthy soil structure that will be both more productive, allow better water infiltration, and be less likely to erode away. Soil erodibility increases as aggregate stability decreases. Soils with stable aggregates are better able to withstand the destructive forces of rain, and are less susceptible to runoff.

Total soil carbon (of which soil organic matter is a portion) can be an indicator of a soil's ability to hold water, store and supply nutrients for the plants, provide food for soil biological organisms and help to maintain good soil structure. Bulk density can be an indicator of soil compaction, infiltrability, and a healthy soil structure.

Previous studies have shown that SAC and carbon levels tend to decrease under annual cropping systems, but can be maintained or increased with the addition of perennials or even small grains to the crop rotation (Sparling et al., 1992, Haynes et al., 1991, Haynes and Swift, 1990, Studdert et al., 1997). Both SAC and soil carbon tend to be higher in pastures and other grasslands than in cropland.

Our hypotheses were that soil carbon, stable aggregate content, and total soil nitrogen would be higher with longer crop rotations, with the addition of perennials, and with rotational grazing; and that bulk density would be lower in those same systems. We hypothesized that animal impact (presence or absence of grazing) would have little if any impact on soil health indicators.

Materials and Methods

Field sites

Data was collected on farms of PFI members and on farms of one or two of their neighbors who used different farming practices. These groups of farms are considered "pods." Pods are located near Fairfield, South English, Maxwell, Harlan, Paullina, Sutherland, Holstein, New Albin, Giard and McGregor, IA. The farmers in each pod selected sampling locations using their County Soil Series book. The sampling locations are the same soil type and position on the landscape but different farming practices for at least the past 5 years with several locations having more than 10+ years of the same farming practice. We have geolocated each location so that multiple years of data can be collected.

Sample Collection

One soil core at the 1-7 inch depth from the soil surface was taken at each location to measure bulk density, soil moisture, and stable aggregate content (SAC). In addition, three 0.75 inch soil cores fractioned into 4 depths: 0-6, 6-12, 12-24 and 24-36 inches were collected near the geolocated site to measure total carbon, total nitrogen, pH, and soil texture. All cores from each depth at each location were bulked into one sample for processing and analysis. To accurately compare the cumulative effect of the farming practice on soil characteristics, we sampled in the middle of the growing season to avoid potential influences from short-term field practices inherent to the annual cropping system conducted in the spring and fall. The treatments from which we sampled are described in Appendix A.

Laboratory Analysis

Bulk density was determined by drying the soil at 105°C and weighing it, then dividing the dry weight by the volume of the sample. SAC was determined by the method described in Patton et al. (2001). Soil samples for total carbon and total nitrogen were air dried and ground to pass through a 2 mm sieve. Total carbon and total nitrogen were determined by dry combustion using a Leco C/N Analyzer (Leco Corporation, St. Joseph, MI). Carbon content was calculated by multiplying the percent total carbon by the bulk density, then multiplying by 6.79 to convert to tons of carbon/A.

Data Analysis

Data were analyzed using a mixed model, and using a Tukey test to determine differences between individual means. Total carbon, total nitrogen, and carbon content were log-transformed for analyses. All reported means are the least-squares means. All data analyses were performed using JMP8.

The treatments were classified into management categories for analysis purposes. This was partially because the samples from each location were bulked, so locations were used as replications. The categories used were vegetation type: annual, multi-year (perennials as part of a crop rotation), or perennial (always in perennial vegetation); rotation length (crop fields only): short (two-year or less rotation) or long (three or more years); animal impact: yes or no (delineates only whether grazing

Table 1

		Total C (0-36 in.)	Total C (0-6 in.)	Carbon Content (0-6 in.)	Total N (0-36 in.)	SAC (0-6 in.)
		%	%	tons/A	%	%
Vegetation type	Perennial	1.17a	2.35	21.9	0.130	67.4 a
	Multi-year	0.98 ab	1.82	17.4	0.118	46.9 ab
	Annual	0.96 b	2.02	18.8	0.130	35.8 b
Presence of grazing animals	Grazing	1.27	2.37a	23.1 a	0.125	71.2
	No grazing	1.20	1.75 b	17.8 b	0.131	39.1
Grazing management	Continuous grazing	1.52	3.27	28.9 a	0.171	83.9 a
	Rotational grazing	1.07	1.86	18.9 b	0.105	66.7 b
Crop rotation length	Long rotation	1.14	1.90	17.1	0.107a	36.7
	Short rotation	1.26	2.08	19.7	0.087 b	31.4

Summary of statistically significant data. Values with different letters within the same column and category are statistically significant ($p<0.05$).

animals were present); pasture rotation intensity (pasture treatments only): rotational graze (animals moved at least every five days with at least 21 days of rest between grazings) or continuous graze; and year-round cover: yes or no. These categories allowed us to group treatments and conduct analyses depending on the different management factors. Refer to Appendix A to see how specific treatments were categorized.

Results

Total Soil Carbon

Sample depth was significant ($p<0.05$). The surface depth of 0-6 inches had the highest with a mean total carbon level of 1.95%. The bottom two depths of 12-24 and 24-36 inches had the least amount of carbon, with 0.74% and 0.61%, respectively.

Treatments with perennial vegetation had significantly higher soil carbon levels than treatments with annual vegetation ($p<0.05$). Soil carbon levels in treatments with perennials as part of a crop rotation were not significantly different from either annual or perennial vegetation.

When individual depths were analyzed separately, the only significant differences ($p<0.05$) observed were the presence (2.37% total carbon) or absence (1.75%) of grazing animals, and only at the 0-6 inch depth. Measured total soil carbon was significantly different ($p<0.05$) between some of the farm pods, but no geographic trends were observed.

Carbon Content

Continuously grazed pastures had on average 28.9 tons of carbon per acre in the top six inches of soil, which was significantly greater ($p<0.05$) than the average carbon content of rotationally grazed pastures, which was 18.9 T/ac.

Carbon content in treatments with grazing (23.1 T/A) was significantly greater ($p<0.01$) than the carbon content in treatments with no grazing (17.8 T/A).

Bulk Density

Soil bulk density was not significantly different among the different treatments.

Total Soil Nitrogen

Within the row crop systems, rotation length had a significant effect ($p<0.05$). Fields with a long rotation, with an average of 0.107%, had significantly higher total nitrogen levels than fields with a short rotation, with an average of 0.087%.

Stable Aggregate Content

Within all farming systems, vegetation type was the only significant effect ($p<0.05$). Treatments with perennial vegetation had an average of 67.4% stable aggregates, which was significantly higher than the treatments with annual vegetation, which had an average of 35.8% stable aggregates. The treatments with perennials as part of a crop rotation had an average of 46.9% stable aggregates, which was not significantly different from either of the other two vegetation types.

Continuously grazed pastures had an average of 83.9% stable aggregates, which was significantly higher than the stable aggregate percentage in rotationally grazed pastures of 66.7%.

Conclusions

Growing perennials instead of annuals appears to be the most important factor in improving soil health, as treatments with perennial vegetation had both higher total soil carbon and stable aggregate content than treatments with annual vegetation. Including perennials in a crop rotation appears to encourage an intermediate level of soil health. This is consistent with the results of other studies as well (Chan et al., 2001, Haynes et al., 1991, Haynes and Swift, 1990, Sparling et al., 1992, Studdert et al., 1997, Yamashita et al., 2006). One study found that soil carbon levels could be maintained by including at least three years of pasture in a crop rotation (Studdert et al., 1997).

Pasture management had a different effect than we expected, as the continuously grazed pastures had both higher carbon content and higher stable aggregate content than the rotationally grazed pastures. One possible explanation for this is that some of the sites under rotational grazing management were more recently converted back to pasture after being degraded for many years by cropping in areas that possibly should not have been cropped due to their topography. It often takes longer for soil carbon levels to be raised than to maintain soil levels (Chan et al., 2001, Haynes and Swift, 1990, Sparling et al., 1992, Studdert et al., 1997). Increases in microbial biomass carbon (which we did not measure) and aggregate stability are often observed before increases in total soil carbon (Haynes et al., 1991, Haynes and Swift, 1990, Sparling et al., 1992), and soil carbon levels in some studies have not been observed to ever reach the levels *of natives grasslands in some studies (Guzman and Al-Kaisi, 2010, Sparling et al., 1992).*

In conclusion, these data support our hypothesis that soil carbon and SAC will be higher under perennial vegetation, but do not support our hypothesis that soil carbon and SAC will be higher with rotational grazing than continuous grazing. Our hypothesis that soil nitrogen would be higher with longer crop rotations was also supported by the data. There were no significant differences to support or refute our other hypotheses. Data will be collected on a subset of these locations for two more years.

References

Chan, K.Y., A. Bowman, and A. Oates. 2001. Oxidizable organic carbon fractions and soil quality changes in an Oxic Paleustalf under different pasture leys. Soil Sci. 166(1):61-67.

Guzman, J.G., and M.M. Al-Kaisi. 2010. Soil carbon dynamics and carbon budget of newly-reconstructed tall-grass prairies in South Central Iowa. J. Environ. Qual. 39:136-146.

Haynes, R.J., R.S. Swift, and R.C. Stephen. 1991. Influence of mixed cropping rotations (pasture-arable) on organic matter content, water stable aggregation and clod porosity in a group of soils. Soil Till. Res. 19(1):77-87.

Haynes, R.J., and R.S. Swift. 1990. Stability of soil aggregates in relation to organic constituents and soil water content. European J. Soil Sci. 41(1):73-83.

Patton, J., L. Burras, M. Konen, and M. Molstad. 2001. An accurate and inexpensive apparatus and method for teaching and measuring stable aggregate content of soils. J. Nat. Resour. Life Sci. Educ. 30:84-88.

Sparling, G.P., T.G. Shepherd, and H.A. Kettles. 1992. Changes in soil organic C, microbial C and aggregate stability under continuous maize and cereal cropping, and after restoration to pasture in soils from the Manawatu region, New Zealand. Soil Till. Res. 24(3):225-241.

Studdert, G.A., H.E. Echeverria, and E.M. Casanovas. 1997. Crop-pasture rotation for sustaining the quality and productivity of a Typic Argiudoll. Soil Sci. Soc. Am. J. 61:1466-1472.

Yamashita, T., H. Flessa, B. John, M. Helfrich, and B. Ludwig. 2006. Organic matter in density fractions of water-stable aggregates in silty soils: Effect of land use. Soil Biol. Biochem. 38(11):3222-3234.

Appendix A

Location	Treatment	Vegetation type	Rotation length	Presence of grazing	Pasture Rotation Intensity
Holstein	Continuous graze	perennial	n/a	yes	continuous
Holstein	Prairie	perennial	n/a	no	n/a
Holstein	Rotational graze	perennial	n/a	yes	rotational
Paullina	Continuous graze	perennial	n/a	yes	continuous
Paullina	Conventional crop	annual	short	no	n/a
Paullina	Conventional crop*	annual	short	no	n/a
Paullina	Corn longer rotation	annual	long	no	n/a
Paullina	Rotational graze	perennial	n/a	yes	rotational
Sutherland	Conventional crop	annual	short	no	n/a
Sutherland	Corn longer rotation	annual	long	no	n/a
Sutherland	Hayground	multi-year	n/a	no	n/a
Giard	Continuous graze	perennial	n/a	yes	continuous
Giard	Corn longer rotation	annual	long	no	n/a
Giard	Rotational graze (2)	perennial	n/a	yes	rotational
McGregor	Conventional crop	annual	short	no	n/a
McGregor	Rotational graze (1 yr)	perennial	n/a	yes	rotational
McGregor	Rotational graze (10 yrs)	perennial	n/a	yes	rotational
New Albin	4-paddock graze	perennial	n/a	yes	continuous
New Albin	Continuous graze	perennial	n/a	yes	continuous
New Albin	Rotational graze (2)	perennial	n/a	yes	rotational
New Albin	Small grain	annual	long	no	n/a
New Hampton	Conventional crop (3)	annual	short	no	n/a
New Hampton	Corn longer rotation	annual	long	no	n/a
New Hampton	Hayground	multi-year	n/a	no	n/a
New Hampton	Trees	perennial	n/a	no	n/a
Maxwell	Conventional crop	annual	short	yes	n/a
Maxwell	Hayground	perennial	n/a	no	n/a
Maxwell	Rotational graze	perennial	n/a	yes	rotational
Fairfield	Continuous graze	perennial	n/a	yes	continuous
Fairfield	Conventional crop	annual	short	no	n/a
Fairfield	Rotational graze	perennial	n/a	yes	rotational
South English	Conventional crop (2)*	annual	short	no	n/a
South English	Hayground	perennial	n/a	no	n/a
Harlan	Conventional crop	annual	short	no	n/a
Harlan	Corn longer rotation (2)	annual	long	no	n/a
Harlan	Hayground	multi-year	n/a	no	n/a
Harlan	Rotational graze	perennial	n/a	yes	rotational