A Report on the Southwest North Dakota Soil Health Demonstration Project Site 2008-2016

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Abstract

A soil health demonstration project was initiated in western North Dakota in 2008 to improve the soil health awareness and knowledge of area producers. Several soil health parameters were measured during the demonstration that indicate that soil health had improved significantly by 2016, particularly water infiltration and nitrogen availability for crop production.

Introduction

The SW ND Soil Health Demonstration Project, located on the NE ¼ of Section 24, Township 143 North, Range 96 West in Dunn County, ND, approximately two miles south of Manning, ND (see Figure 1) was a joint project of the Dakota West Resource Conservation and Development Council, Dunn County Soil Conservation District, Western and Central Stark County Soil Conservation District, United States Department of Agriculture Natural Resources Conservation Service, Dickinson State University and North Dakota State University Dickinson Research and Extension Center. The demonstration project was conducted with funding from a United States Department of Agriculture Sustainable Agriculture Research & Education (SARE) grant from 2008 through 2012. Objectives of the demonstration project were to improve awareness and knowledge of soil health among producers and resource professionals in southwestern North Dakota, motivate producers to implement practices on their own operations that would improve soil health, and demonstrate a cropping system utilizing no-till and cover crops to improve soil health. Soil health is defined as the continued capacity of soil to function, particularly in the areas important to crop production and environmental protection, such as water infiltration and plant nutrient cycling.

Materials and Methods

A diverse crop rotation of three years of alfalfa, winter triticale/hairy vetch, corn, oats/peas, a multi-species cover crop, spring wheat, and winter wheat, was implemented during the study on all eight fields. Planting was accomplished with a John Deere 1590 disc-opener no-till drill. All crops received commercial fertilizer when recommended by annual soil test reports (see Table 2). The multi-species cover crop included up to 10 species of warm and cool season grasses, legumes and brassicas. From 2012 through 2016, the demonstration project fields continued to be planted without tillage and fertilized according to soil test recommendations though the crop rotation was modified slightly to adjust for weather conditions (see Table 3 in Appendix). This project was designed and executed for demonstration and education purposes and not as replicated research; the results are provided as observed without a control to serve as a standard for comparison. However, the results illustrate positive changes in soil health that suggest that further study would be worthwhile.

Sampling sites were located in each field and samples analyzed for Nitrogen, Phosphorous, Potassium, pH, soluble salts, and organic matter by a commercial laboratory. Water infiltration tests for an initial and second inch of water, were conducted in 2008 on fields 1 and 4, on all fields in 2011, and again in 2016 utilizing a single 6-inch tall by 6-inch diameter metal ring driven four to five inches into the soil. An inch of water was applied inside the ring and water infiltration into the soil timed and recorded. The procedure was then repeated with a second inch of water. This procedure was conducted in three locations within each field to achieve an average infiltration rate for the field.

Soil samples for biological analysis were collected from 0 - 3'' in 2008, 2011 and 2016. Samples were sent to Earthfort^M in Corvallis, OR for analysis that included: active bacteria, total bacteria, active fungi, total fungi, fungal hyphal diameter, flagellate protozoa, amoebate protozoa, ciliate protozoa, total nematodes, nematode species (bacterial, fungal, fungal/root and root feeding) and potential nitrogen cycling capacity.

Results

The most dramatic positive changes in soil health on the site from 2008 to 2016 were the increase in the rate of water infiltration into the soil and the increase in plant nutrient cycling expressed as biologically generated plant available nitrogen. See Table 1 below for changes in each parameter measured over the 2008 to 2016 demonstration time period.

Other notable changes were a slight increase in soil pH, a slight decrease in soil salinity (Electrical Conductivity), a slight increase in soil organic matter and significant increase in the number of protozoa and the number and diversity of nematodes.

2008 or 2011 Benchmark	2016	Net Change	Percent Change	Soil Property 0"-6" depth			
2.5	44.8	42.3	1699%	Water infiltration first inch (in/hr.)*			
1.3	10.2	8.9	685%	Water infiltration second inch (in/hr.)*			
32.5	21.5	-11.0	-34%	Nitrate (ppm) 0 - 24"			
49.1	21.3	-27.8	-57%	Phosphorous (ppm)			
364.4	252.1	-112.3	-31%	Potassium (ppm)			
6.9	7.0	0.1	1%	рН			
0.6	0.3	-0.3	-52%	Electrical Conductivity (dS/m)			
2.7	3.0	0.3	11%	Organic Matter (%)			
28.4	7.9	-20.5	-72%	Active Bacteria (μgr/gr)			
904.1	981.7	77.6	9%	Total Bacteria (μgr/gr)			
4.8	3.5	-1.3	-27%	Active Fungal (µgr/gr)			
179.8	170.6	-9.2	-5%	Total Fungal (μgr/gr)			
2.9	2.9	0.0	0%	Hyphal Diameter (μm)			
5,670.1	4,489.0	-1,181.1	-21%	Flagellate Protozoa (no/gr)			
11,489.1	404,703.2	393,214.1	3422%	Amoebate Protozoa (no/gr)			
58.1	135.6	77.5	133%	Ciliate Protozoa (no/gr)			
6.2	13.4	7.2	116%	Total Nematodes (no./gr)			
4.4	6.3	1.9	43%	Species of Bacterial Feeding Nematodes (no.)			
2.4	4.2	1.8	75%	Species of Fungal Feeding Nematodes (no.)			
2.9	2.9	0.0	0%	Species of Fungal/Root Feeding Nematodes (no.)			
1.8	0.7	-1.1	-61%	Species of Root Feeding Nematodes (no.)			
100.0	275.0	175.0	175%	Plant available N supply (lbs./ac.)			

Table 1: Net change of soil properties from first measurement to 2016 measurement.

*Water infiltration benchmark measurements on Fields 1 & 4 were made in 2008, other fields in 2011.

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Figure 1: Southwest North Dakota Soil Health Demonstration Project Site NE 1/4 Section 24 T143N R96W, Dunn County, ND





Legend



NAD 1983 StatePlane ND South Projection: Lambert Conformal Conic Jon Stika 2017





Water runs off of field 2408 on June 2, 2008 after .3" of rain over the course of the day. In 2016, water infiltration on field 2408 was 2.5" per hour.

Discussion

Water infiltration into the soil controls the water that is available for plant growth. Water that does not infiltrate the soil either runs off of the field or ponds and evaporates. Water that runs off of the field is no longer available for crop production and may cause soil erosion. During water infiltration testing, the first inch of water that infiltrates into the soil is greatly influenced by soil moisture at the time that the measurement is conducted. Once the soil is moistened by the first inch of applied water, the second inch of water infiltration better illustrates the stability of soil aggregates and pores to continue to allow water to enter the soil. The observed increase in water infiltration of nearly nine inches per hour on the demonstration fields over the eight years of the project suggests that managing with the intent of creating favorable habitat for soil microorganisms can lead to an increase in the biological glues that stabilize soil aggregates and soil pores. Water infiltrating into the soil is critical for both plants and soil microorganisms' growth and productivity.

The decrease in nitrate nitrogen, phosphorous and potassium shown by conventional soil testing methods seems to contradict the increase in plant available nitrogen supply shown by the Earthfort[™] biological soil analysis. However, it should be noted that conventional soil testing is based upon chemical extraction of measured nutrients from the soil and the corresponding fertilizer recommendations are based on how soils that experience regular tillage react to the addition of fertilizers. Since the soils in the demonstration project fields were not tilled for eight years, the soil environment and biology changed significantly. As soil health improved, more of the nitrogen and other crop nutrients in the soil were present in biological forms rather than ionic (chemical) forms and thus less prone to loss by leaching or volatilization; but less measureable by standard soil testing methods.

The soil nitrogen cycling potential provided by Earthfort[™] analyses is based on the populations and balance of predators (primarily protozoa and nematodes) to prey (primarily bacteria and fungi). When bacteria and fungi are consumed by protozoa and nematodes the excess nitrogen that occurs is excreted into the soil by the predators. With a moderate increase in total bacteria, a slight decrease in total fungi, a significant increase in the number of protozoa, and increases in the number and diversity of nematodes in the soil, both predators and prey are currently sufficient in the demonstration field soils to produce a high rate of nitrogen cycling. The average nitrogen cycling potential across all eight fields of the demonstration project in 2016 was 275 pounds/acre/year of plant available nitrogen. A typical spring wheat crop of 40 bushels/acre in western North Dakota will need approximately 120 pounds of actual nitrogen. Nitrogen supplied by soil microorganisms in aerobic healthy soil is rarely subject to leaching into water or volatilization into the air. This increased nitrogen cycling potential suggests that commercial nitrogen fertilizer may no longer be needed to supply the nitrogen needs of crops grown in the demonstration project fields.

The slight increase in soil pH observed during the period of the demonstration project is the opposite of what is typically observed in cropland soils of the Great Plains where soil pH has been declining due to the continued use of ammonium based nitrogen fertilizer (Schroder et. Al. 2011). Maintaining soil pH near neutral (7.0) is important for nutrient availability and uptake by crops.

The slight decrease in measured soil salinity may be the result of increased water infiltration leaching soluble salts deeper into the soil. Soil salinity was not measured below six inches. This trend of reduced soil salinity may decrease more rapidly if the use of commercial fertilizer (most of which are salts) is reduced or suspended. Soil salinity is a major issue in many agricultural soils in North Dakota. A reduction in soil salinity by improving soil health and water infiltration into the soil would benefit producers where salinity is a limitation to crop production.

The slight increase in soil organic matter is encouraging and suggests that continued management of the soil as a biological system should result in a continued increase in soil microorganisms and their aggregatestabilizing byproducts that retain carbon in the soil. Soil organic matter may increase at a greater rate if crops grown for forage are fed to livestock on the fields where the forage originates instead of being exported from the field and fed elsewhere. Carbon retained in the soil benefits many soil functions and reduces the amount of carbon dioxide in the atmosphere.

Protozoa are predators of bacteria in the soil. Among protozoa, flagellates are the relatively smaller species, followed by amoebae, with ciliates being the largest. Flagellate and amoebate protozoa typically range in number from 10,000 to 100,000 per gram of soil. Ciliates typically occur at 0 to 200 per gram of soil. 2016 soil analysis showed an average of 4,489 flagellate protozoa, 404,703 amoebate protozoa, and 136 ciliate protozoa per gram of soil. Thus, the flagellate protozoa were somewhat below the expected range, amoebate protozoa significantly above the expected range, and ciliate protozoa within the expected range. The high populations of protozoa, combined with the high populations of bacteria (average of 982 µgr/gram soil with an expected range of 300 – 600 µgr/gram soil) sets the stage for the exceptional nitrogen cycling mentioned previously. The more nitrogen that is captured from the atmosphere and cycled through the soil biologically, the less nitrogen fertilizer will be needed to support crop yields at a significant cost savings to producers.

Nematodes also serve as predators in the soil; consuming bacteria, fungi, plant roots and other nematodes. The

7.2 increase in nematode populations per gram of soil over the demonstration project period also contributes to increased nitrogen cycling. The diversity of bacterial and fungal feeding nematodes increased, while the diversity of fungal/root feeding nematodes remained the same, and the species of nematodes that feed exclusively on plant roots decreased by 1.1 species. This bodes well for both nitrogen cycling and reduced predation of plant roots by nematodes. Again, this can reduce the cost of nitrogen fertilizer inputs to achieve desired crop yields.

Conclusions

The positive changes noted in several critical soil health parameters of water infiltration, nitrogen cycling, pH, salinity, and organic matter over the life of the soil health demonstration project is very encouraging and suggests areas for further scientific study. Water infiltration into the soil is critically important for

crop production in western North Dakota where precipitation is often limited during the growing season. Water that infiltrates into the soil also does not contribute to soil erosion and offsite surface water impairment. Nitrogen captured from the atmosphere and cycled through the soil biologically provides this vital nutrient to crops as they need it and can significantly reduce the need for purchased nitrogen inputs. Soil pH is important to nutrient availability to crops. Soil that is buffered biologically can maintain a favorable pH for crop production. Increased water infiltration not only provides water for crop production, but helps move salts deeper into the soil where they are less detrimental to the establishment of crop seedlings. Organic matter is at the heart of soil health and increases in both quantity and quality to improve all aspects of soil function. Soil organic matter has declined significantly from the levels originally found in soils across North Dakota prior to settlement and the plow. Restoring soil organic matter is a major indicator of restoring soil disturbance, (2) increased plant species diversity, (3) maintaining living roots in the soil as much time as possible, and (4) keeping the soil covered at all times, (Stika 2016) can improve soil health in all parts of North Dakota (and the nation) as evidenced by what was observed on the southwest North Dakota soil health demonstration fields.

References

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Appendix

2008* 2009*	8.57 13.2	6.87 10.86	* Data from the NDAWN (N Network) site at the Dickir in Dickinson, ND approxim						
2010	13.96	12.7	Southwest North Dakota S						
2011	16.52	14.24		site. 2010 - 2017 data are from the SW Dunn NDAWN station approximately 12 miles northeast of the Southwest North Dakota Soil Health Demonstration Project site, or .5 mile					
2012	11.39	7.71							
2013	22.56	18.31		southwest of Dunn Center, ND.					
2014	18.12	16.96							
2015	16.45	14.36	ł May-July						
2016	18.84	12.84	‡January-July						
2017	3.31‡	2.88 1	Average Annual Precipitat						