Assessment of Cropping System Effects on Soil Quality in the Great Plains: Introduction

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Abstract
Soils serve a multitude of functions and play an important role in environmental quality through interactions with the hydrosphere and the atmosphere. Long-term studies are usually required to compare management effects on the soil resource to make soil quality assessments. This requirement exists because of the effect annual variations in weather has on the system and also because we are often trying to detect changes in the value of large pools exhibiting spatial variability. In protocols established by the Great Plains Cropping System Network in 1998, sampling and testing procedures were selected to identify components or fractions of larger pools that are responsive to management that may serve as indicators of changes in the larger pool, which would be useful in assessing the effect management practices have on the soil resource. Several existing long-term studies are available in the region and these locations and the selected conventional and alternative treatments selected for soil quality assessments are described in the paper. Precipitation, temperature, and yield data for each location are also presented.

Introduction
Soils serve a multitude of functions and play an important role in environmental quality through interactions with the hydrosphere and the atmosphere. Management of the soil resource affects how efficiently the soil performs its various functions and ultimately impacts environmental quality. There is currently a great deal of interest in improving our understanding of how soils interact with the hydrosphere and atmosphere; in developing management practices that improve the capacity of the soil to perform its various functions; and in identifying physical, chemical, and biological soil attributes that can be used to quantify the present state of the soil and detect changes in the state of the soil resulting from management.

A number of physical, chemical, and biological soil attributes have been proposed for use in assessing soil quality. Several lists of attributes have been suggested for comprising a minimum data set and combinations of attributes have been incorporated into indices having potential for assessing soil function and management impacts. A large number of studies have been conducted comparing various soil quality attributes under different management systems (e.g. comparing crop fallow to annual cropping, conventional tillage to conservation tillage, or conventional farming to organic farming). These studies are of value in quantifying the magnitude of the differences in the various soil attributes under different management systems, creating a data set that can be used to determine the range and expected value of the various soil attributes, and improve our understanding of the effect management practices have on the soil resource.

Long-term studies are usually required to compare management effects on the soil resource. This requirement exists because of the effect annual variations in weather has on the system and also because we are often trying to detect changes in the value of large pools exhibiting spatial variability. In protocols established by the Great Plains Cropping System Network in 1998, sampling and testing procedures were selected to identify components or fractions of larger pools

Bushland: The experimental plots are located on graded-terraced watersheds at the USDA-ARS Conservation and Production Research Laboratory on Pullman clay loam (fine, mixed, superactive, thermic Torrertic Paleustoll). These plots mainly consist of wheat-sorghum-fallow and continuous wheat cropping systems managed under no tillage or stubble-mulch tillage since 1983. The terraces have an organic carbon content of 10 g kg^{-1} (0-15 cm) and medium and very high levels of P and K, respectively. The specific treatments selected from this experiment for soil quality assessments were continuous winter wheat and a single-phase of the wheat-sorghum-fallow rotation, both under no-tillage management. The plots received no fertilizers throughout the duration of the study. Jones and Popham (1997) provide further details of weed control, experimental layout, and cultural practices for these long-term plots.

Fargo: This dryland experiment covering 2 hectares is located 8 kilometers NW of Fargo, ND on the NW22 research land of the North Dakota Agricultural Experiment Station. The soil is mapped as a Fargo silty clay (fine, smectitic, frigid, Typic Epiaquert) with average soil tests in the 0-15 cm depth of 41 g kg^{-1} organic matter, a 1:1 pH of 7.7, phosphorus at 47 kg ha^{-1} and potassium at 629 kg ha^{-1}. A tillage system study was initiated at this site in the fall of 1977 with four primary tillage systems after the small grain crop including fall plow, fall sweep, fall intertill (strip till) and no-till. Each tillage block was 14 m wide by 32 m long and replicated four times. A rotation of sugarbeet, spring wheat, sunflower and barley was maintained the first eight years. Sugar beet was replaced by soybean in the rotation during the next two years and the sweep system was changed to fall chisel. In 1987, the rotation was switched to a small grain and grain legume rotation that included spring wheat, durum, soybean, drybean, and field pea. In the spring of 1997 a N fertilizer variable was added to the study with 0, 45, 90 and 135 kg N ha^{-1} randomly split across each replication. The specific treatments selected for this study were the plow and no-till tillage systems for the small grain (durum wheat even years) and grain legume (field pea odd years) rotation without nitrogen fertilizer. Specific details are available in Deibert (1989, 1995).

Mandan: The experiment was located about 6 km southwest of Mandan, ND on a Wilton silt loam (fine-silty, mixed, superactive frigid Pachic Haplustoll). The site had a soil pH of 6.4 and an organic C concentration of 21.4 g kg^{-1} in the surface 76 mm. Sodium-bicarbonate extractable P in the surface 152 mm ranged from 20 to 26 mg kg^{-1} in the spring of 1984. The experiment was initiated in 1984 and was rainfed.

Two crop sequences, three residue managements, three N fertilizer rates, and two crop cultivars were included in the research. Three replicates of crop sequences (137.2 by 73.1 m), residue management (45.7 by 73.1 m), N fertilizer rates (45.7 by 24.4 m), and crop cultivars (22.8 by 24.4 m) were arranged in a randomized complete block design. Specific treatments selected for the soil quality assessments were the spring wheat-fallow with conventional residue management (< 30% soil surface covered by residue), and 22 kg N ha^{-1} as the conventional system and the spring wheat–winter wheat–sunflower with no-tillage residue management (> 60% soil surface covered by residue), and 67 kg N ha^{-1} as the alternative system. Detailed soil characterization and management information have been described by Black and Tanaka (1997).

Mead: The experiment is located on the Agronomy Farm at the University of Nebraska Agricultural Research and Development Center near Mead, Nebraska on a well-drained Sharpsburg silty clay loam (fine, smectitic, mesic Typic Argiudoll). This site has an average organic matter content of 31 g kg^{-1} and soil test P and K levels in the very high categories in the surface 75 mm. The experiment was initiated in 1982 and is rainfed.

Seven cropping systems (three monoculture, two two-year, and two four-year rotations) with three rates of N fertilizer are included in the study. Each phase of every rotation occurs every year

Pikul, Jr., J.L., C. Carpenter-Boggs, M. Vigil, T.E. Schumacher, M.J. Lindstrom, and W.E. Riedell. 2001. Crop yield and soil condition under ridge and chisel-plow tillage in the northern Corn Belt, USA. Soil & Tillage Res. 60:21-33.

Riedell, W.E., T.E. Schumacher, S.A. Clay, M.M. Ellsbury, M. Pravecek, and P.D. Evenson. 1998. Corn and soil fertility responses to crop rotation with low, medium, or high inputs. Crop Sci. 38:427-433.

Table 2. Monthly and yearly average temperatures and long-term averages at each location.

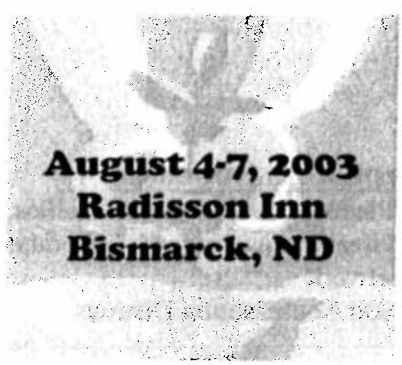
Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Yearly Mean
	Month												
	Mean Temperature (°C)												
Akron, CO													
1999	0.8	3.6	5.3	6.8	15.0	18.5	23.8	26.1	14.9	10.2	6.9	0.4	11.0
2000	-0.7	2.6	4.5	8.7	13.5	19.1	23.9	27.2	16.9	10.0	-2.2	-3.4	10.0
2001	-2.0	-3.0	2.7	9.4	13.6	20.0	24.5	26.4	17.9	10.5	5.0	-0.6	10.4
2002	-1.4	-0.1	0.1	9.5	13.1	22.3	24.5	22.0	17.0	7.1	2.1	2.1	9.8
Ave.†	-3.7	-0.9	2.4	8.1	13.5	19.2	23.0	22.0	16.9	10.2	2.6	-2.4	9.2
Brookings, SD													
1999	-12.3	-3.6	-0.2	6.6	14.3	18.9	22.8	20.2	14.3	7.2	4.2	-4.9	7.3
2000	-9.4	-3.0	3.4	5.9	14.3	18.2	21.2	20.7	14.5	9.6	-4.0	-14.6	6.4
2001	-9.1	-13.9	-5.4	6.5	14.4	19.1	22.8	21.6	15.3	7.3	5.7	-5.4	6.6
2002	-7.1	-2.9	-7.9	6.1	10.9	20.8	24.0	20.2	16.3	3.8	-7.2	-5.1	6.0
Ave.†	-12.3	-9.2	-1.7	6.5	13.1	18.6	21.4	19.9	14.4	7.8	-0.8	-9.2	5.7
Bushland, TX													
1999	3.9	6.7	7.2	11.7	15.6	21.7	25.0	25.0	18.9	13.9	11.1	1.7	13.5
2000	3.3	7.2	8.3	13.9	20.6	22.2	25.6	26.7	22.2	14.4	3.3	-0.6	13.9
2001	-0.3	2.9	6.1	14.8	17.6	24.3	28.0	24.6	20.5	14.7	9.2	3.1	13.8
2002	2.7	2.9	6.7	14.6	18.8	25.0	25.0	24.8	19.9	11.1	6.0	1.2	13.2
Ave.†	1.7	4.0	7.7	12.9	17.8	22.9	24.9	24.0	20.1	14.2	7.3	2.8	13.4
Fargo, ND													
1999	-14.2	-5.3	-0.4	7.3	14.4	19.1	21.9	20.0	13.0	6.8	2.8	5.0	6.7
2000	-12.3	-5.8	1.8	5.8	14.0	17.0	21.4	20.9	14.4	9.0	-3.3	-17.6	5.4
2001	-9.8	-15.6	-5.0	6.9	14.7	18.8	22.5	21.4	15.2	6.9	4.3	-6.6	6.2
2002	-8.6	-4.4	-6.7	4.5	10.7	20.6	22.8	19.6	16.5	2.9	-2.3	-6.7	5.7
Ave.†	-14.0	-9.9	-2.7	6.4	14.1	18.9	21.4	20.6	14.4	7.4	-2.8	-10.8	5.3
Mandan, ND													
1999	-12.5	-3.8	1.2	5.9	12.4	17.3	21.0	19.7	11.9	6.8	3.4	-3.3	6.7
2000	-9.0	-4.8	1.4	5.9	13.4	16.2	20.8	20.4	14.5	8.5	-5.2	-14.8	5.6
2001	-6.5	-13.4	-1.6	6.7	13.8	17.1	21.4	21.9	15.2	5.8	2.7	-6.4	6.4
2002	-6.8	-3.8	-8.1	4.0	10.1	19.1	22.9	19.6	15.3	1.7	-0.3	-4.8	5.7
Ave.†	-12.2	-8.3	-1.7	6.1	13.3	18.3	21.1	20.6	13.9	7.2	-2.2	-9.4	5.6
Mead, NE													
1999	-5.2	1.3	3.5	10.6	16.2	20.9	26.4	22.3	17.1	11.2	7.7	-1.0	10.9
2000	-3.1	1.6	6.6	10.6	18.8	21.4	23.8	23.8	19.5	13.4	-0.2	-9.8	10.6
2001	-3.5	-6.5	1.7	12.5	17.3	21.8	25.9	24.0	18.1	11.5	8.9	-0.7	10.9
2002	-1.6	-1.2	0.1	11.1	15.3	24.9	26.8	23.6	19.4	8.0	2.4	-0.5	10.7
Ave.†	-5.6	-2.6	3.7	10.9	16.9	22.4	25.2	23.6	18.4	12.1	4.1	-3.4	10.5
Swift Current, SK													
1999	--	--	--	--	--	--	--	--	--	--	--	--	--
2000	-11.5	-7.4	0.1	4.9	10.9	13.9	19.1	18.5	12.4	6.4	-5.0	-13.8	4.0
2001	-5.0	-14.1	-0.7	5.4	12.2	15.0	19.7	20.7	15.0	4.2	1.7	-8.7	5.5
2002	--	--	--	--	--	--	--	--	--	--	--	--	--
Ave.†	-13.3	-10.8	-4.7	4.6	10.9	15.4	18.6	17.6	11.8	5.6	-3.5	-9.6	3.6

† Akron (93-yr), Brookings (30-yr), Bushland (64-yr), Fargo (30-yr), Mandan (30-yr), Mead (30-yr), and Swift Current (117-yr) averages, respectively.

A CROPPING SYSTEMS SYMPOSIUM

DYNAMIC CROPPING SYSTEMS

Principles, Processes, and Challenges



J.D. Hanson and J.M. Krupinsky (Editors)

PROCEEDINGS