Cropping System Effects on Soil Quality in the Great Plains: Summary from a Regional Project

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Abstract

Soils perform a number of essential functions that are often assessed by measuring physical, chemical, and biological properties related to soil functions affecting the management goal. Information is needed on the temporal dynamics of commonly measured soil properties, the sensitivity of these properties to management, and the utility of new methods in soil quality assessments. In 1998, a regional project was initiated to utilize existing long-term cropping system studies at eight locations in the Great Plains to provide this information. The Soil Management Assessment Framework was used to calculate an index for soil properties repeatedly measured under contrasting management practices from 1999 to 2000. Index values were used to detect temporal changes in soil properties and management affects on soil properties. Results indicate soils from semi-arid locations developed under mixed or short grass prairie (Swift Current, SK, Mandan, ND, Akron, CO, and Bushland, TX) are more sensitive to management than soils receiving higher amounts of precipitation and developed under tall grass prairie (Fargo, ND, Brookings, CO, and Mead, NE). Temporal changes were related to weather and crop production differences among years. Differences between management practices were related to the incidence of fallow.

Introduction

Soils perform numerous functions in support of agroecosystems. Soils are a substrate for supporting plant growth, a reservoir for many nutrients essential for plant growth, a filter maintaining air quality through interactions with the atmosphere, a storage and purification medium for water as it passes through the soil, and a site for biological activity involved in the decomposition and recycling of animal and plant products. Physical, chemical, and biological soil properties are often selected to comprise a minimum data set for soil quality assessment of soil functions. Time of year to sample, choice of soil properties to measure, and how to interpret results are challenges to assessing soil functions. Interpretation of results is difficult given the multiple functions soils perform. Furthermore, it is common to observe conflicting results among soil properties. In 1998, the Great Plains Cropping System Network initiated a study utilizing existing long-term cropping system studies throughout the region to address a number of these issues.

The objectives for this regional study were:

1) To quantify the temporal dynamics exhibited by selected physical, chemical, and biological soil quality attributes in the upper 30 cm.
2) To compare selected physical, chemical, and biological soil quality attributes between contrasting management practices in the Great Plains and Western Corn Belt.
3) To assess several recently developed methods for their potential in quantifying soil quality attributes that may be sensitive to management.

Materials and Methods

Contrasting management systems were selected for sampling at eight research sites throughout the Great Plains. Locations participating included: Swift Current, Saskatchewan; Sidney, Montana; Mandan and Fargo, North Dakota; Brookings, South Dakota; Bushland, Texas; Akron, Colorado; and Lincoln (Mead), Nebraska. Contrasting management systems were selected to include a traditional conventional system and an alternative system incorporating best management practices for that location. Best management practices included conservation tillage, crop rotation, and more intensive cropping (Varvel et al., 2003). At some locations, relic areas supporting perennial vegetation on soils similar to those in the treatment plots were sampled. Soils in these relic areas were assumed to represent conditions found in the absence of agricultural practices (e.g. tillage, annual crops, fertilization).

At each location, replicate plots from the two management systems were sampled. Soil samples were collected three times each year from 1999 to 2002. Samples were collected prior to planting of spring planted crops, midseason (e.g. flag leaf for wheat, tassel for corn), and after harvest. Sample time 1 corresponds to the spring of 1999, sample time 4 to the spring of 2000, sample time 7 to the spring of 2001, and sample time 10 to the spring of 2002 (Fig. 1). The number of sampling times varied among locations. Some locations had two or three-year rotations and sampling was limited to that length of time. Others missed some sampling times due to weather related problems. A bulk soil sample was collected from the 0- to 2.5-cm depth for aggregate size distribution, glomalin concentration (Wright and Upadhyaya, 1998), and wet aggregate stability. Additional samples were collected by coring to a depth of 30 cm and each core was sectioned into 0- to 7.5-cm, 7.5- to 15-cm, and 15- to 30-cm increments. Multiple cores were collected from each plot, sectioned and combined by depth to provide a composite sample. This composite sample was used for determining soil chemical, and soil biological (Liebig et al., 2003) properties. In addition to soil aggregate properties, bulk density, gravimetric water content, and infiltration rate were soil physical properties measured (Pikul et al., 2003).

The Soil Management Assessment Framework (SMAF) was used to calculate an index value for each treatment at each sampling time. The SMAF is an additive, non-linear indexing tool for assessing soil management goals (Andrews et al., 2002). Scoring curves available in the most recent version of SMAF and measured in this study were: total organic C, macroaggregate percentage, microbial biomass C, potentially mineralizable N, pH, microbial quotient (relationship between microbial biomass C and mineralizable C), bulk density, and electrical conductivity. These soil properties are indicators of soil functions (nutrient reservoir, substrate for plant growth) related to an agronomic production management goal. As index values increase agronomic yield would be expected to improve. Attribute values for the 0- to 7.5-cm and 7.5- to 15-cm depths were averaged. An index value was calculated for each replication of both treatments at each sampling date. Analysis of variance was used to determine differences among index values between treatments and across sampling times. Differences were considered significant at $P < 0.05$.

Results

Differences between treatments or treatment by time interactions for SMAF index values were observed at Akron, Bushland, Mandan, and Swift Current (Table 1). Temporal variation in SMAF index values was observed at Brookings, Fargo, and Mead. At Sidney, SMAF index values were similar between treatments at all sampled times.

<u>Akron</u> The treatment by time interaction resulted from a decline in index value in the alternate system during the first season but a rise in the index value in the alternative system during the second season (Fig. 1).

Table 1. P-values for main effects and interactions for Soil Management Assessment Framework index values for eight sites in the Great Plains.

Effect	Location							
	Akron	Brookings	Bushland	Fargo	Mandan	Mead	Sidney	Swift Current
	P-value							
Treatment	0.16	0.11	<0.05	0.08	<0.01	0.13	0.83	0.02
Time	0.21	<0.01	<0.01	0.04	<0.01	<0.01	0.11	<0.01
Tmt*Time	<0.01	0.93	0.06	0.67	<0.01	0.08	0.11	0.06

Brookings The time effect resulted from an increase in index value following the first sampling and a decline in index values during the 2001 and 2002 growing seasons (Fig. 1). Between April 2001 and August 2002 precipitation was much below normal resulting in below average yields and lower residue inputs to the soil (Varvel et al., 2003).

Bushland The treatment by time interaction resulted from similar index values at the initial sampling, lower index values between continuous wheat and fallow in 2000, and similar index values between the two systems in 2001 (Fig. 1). Below average precipitation from 2000 to 2002 resulted in low yields and low amounts of residue being added to the soil (Varvel et al., 2003).

Fargo The time effect resulted from a decline in index values during 2000 and an increase in index values from the first sampling in 2001 through the last sampling in 2002 (Fig. 1). The index value for soil under perennial vegetation was similar to that in the annually cropped soil. Precipitation during the study was above average and residue inputs to the soil were above average (Varvel et al., 2003).

Mandan The treatment by time interaction resulted from similar index values across times in the annually cropped system compared to index values in the wheat-fallow system that were similar during the wheat year, declined during the fallow year, and were always lower than index values in the annual cropping system. Index values for soil under perennial vegetation were similar to those in the annually cropped no-tillage system (Fig. 1).

Mead The time effect resulted from a gradual increase in index values during the first two years of the study, a decline in index values from the middle of the second year to the end of the third year, and an initial increase during the fourth year with a decline in the index value for the last sampling period (Fig. 1). Index values for soil under annual cropping were 74% of that for soil under perennial vegetation. Below normal precipitation in 2000 through 2002 resulted in lower than normal yields and below normal residue inputs to the soil (Varvel et al., 2003).

Sidney There was no treatment or time effect observed at this location. The index value for the cropped plots averaged 0.54 and was 70% that for soil under perennial vegetation (index value = 0.77).

Swift Current The treatment effect resulted from index values being lower in the wheat-fallow treatment than in the wheat-lentil treatment (Fig. 1). The time effect resulted from index values in both systems being lower in 2001 than in 2000. Precipitation in 2001 was 50% the normal amount and yields and residue inputs were below normal (Varvel et al., 2003).

Discussion

Soil assessed in this study can be divided into two groups based on management and weather induced changes in soil quality. Soils at Fargo, Brookings, and Mead developed under tall grass prairie are deeper than soils at the other locations. The three eastern sites in this study also receive more precipitation than the other locations resulting in greater annual biomass inputs. The higher precipitation also eliminated the need for summer fallow as a management practice to reduce the risk of crop failure when these soils were brought under crop production. Results from this study indicate management practices affected soil properties to a lesser extent than did environmental factors.

Soils at Swift Current, Mandan, Akron, and Bushland developed under mixed or short grass prairie and a semi-arid environment. These soils tend to be shallower than those to the east. The lower precipitation received at these locations resulted in lower annual biomass inputs and made summer fallow a common practice for reducing the risk of crop failure. Summer fallow has had a well-documented negative effect on soils throughout this region. Results from this study indicate these soils are sensitive to management practices. While soils at Sidney are similar to other locations in this group, no treatment effect was observed. This is likely due to the way soils were sampled at Sidney. At Sidney all phases of all treatments were present each year and in the wheat-fallow treatment soils were sampled from plots under wheat each year. This is in contrast to the other locations having crop-fallow treatments where soils in a plot would have been sampled repeatedly resulting in soil under a crop being sampled one year followed by soils under fallow being sampled the next year.

A number of physical, chemical, and biological soil properties exhibited temporal variability resulting from management and weather influences. However, when comparing management practices, our results suggest time of year is not critical for assessing soil properties. In soils that developed under a semi-arid environment, soil properties differed under contrasting management practices. In areas receiving more precipitation, soil properties were similar under contrasting management practices.

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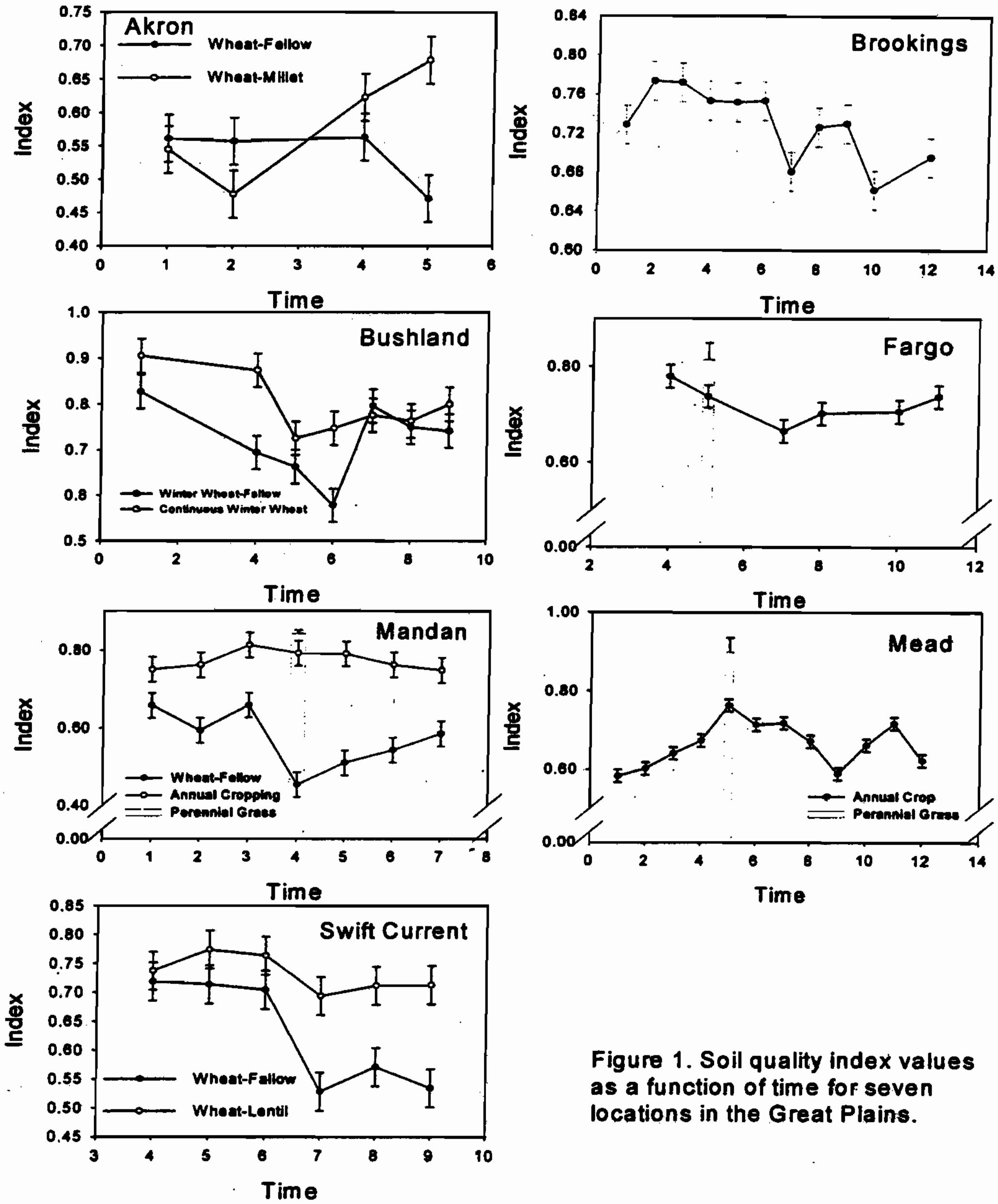
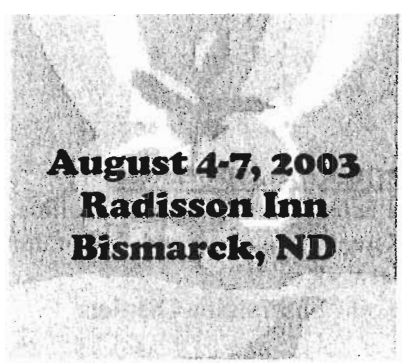


Figure 1. Soil quality index values as a function of time for seven locations in the Great Plains.

A CROPPING SYSTEMS SYMPOSIUM

DYNAMIC CROPPING SYSTEMS

Principles, Processes, and Challenges



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PROCEEDINGS