Temporal Variability of Selected Properties of Two Grand Prairie Soils as Affected by Cropping

H.D. Scott, I.P. Handuyani and A Mauromoustakos[1]

ABSTRACT

Quantification of the temporal variability of soil properties is needed in order to under stand the effects of cropping on soils. A study was conducted to determine the short- and long-term variability of selected soil properties of two loessial soils in the Grand Prairie of Arkansas. The surface 15 cm of both soils had a silt loam texture. Four adjacent fields were used for the study and included a prairie and three fields that had been cropped for 3, 14 and 32 years, respectively. The statistical analyses indicated that the magnitude of the soil properties varies with duration of cropping (long-term variability), depth interval and sampling time within a year (short-term variability). The amount of variability was dependent on soil property. Temporal changes such as increases in soil solution pH up to an optimum pH are beneficial whereas increases in bulk density and decreases in Ksat, total porosity, total C content and the ability to retain or store water generally are considered to be detrimental for maximum crop production. The variability of total C content in the soils could adequately describe the variability of log Ksat, bulk density, porosity and water retained at 10 kPa.

INTRODUCTION

Generally, tillage practices are used to provide more favorable soil conditions for crop growth and development. Moderate tillage facilitates root growth by loosening surface and subsurface soil and improves aeration and water infiltration of the soil profile. On a short-term basis, tillage may be beneficial to crop production and soil productivity (Baver et al., 1973). On the other hand, over many years frequent tillage operations using moldboard plows, disk or chisel or a combination of disk-chisel or disk cultivators have been used within a growing season. The cumulative effect of these frequent tillage operations and cropping leads to changes in soil physical, chemical and biological properties. As a result, extensive tillage of the soil over long periods of time may have detrimental effects on crop establishment and yield.

Temporal variability of soil properties is defined as the changes in the magnitude of soil properties with respect to time. The temporal changes of soil properties can occur over long-term (more than a year) or short-term (equal to or less than a year) periods of time. Temporal variations in soil properties have been reported to be associated with total porosity, bulk density and water retention (Gantzer and Blake, 1978; Cassel, 1983), saturated hydraulic conductivity and macroporosity (Carter, 1988). These soil properties are dynamic even in prairies (never cultivated) where factors such as freezing and thawing, root growth and exudates, wetting and drying cycles, carbon turnover and biological activity may strongly effect their magnitude. This temporal variability is called intrinsic variability (Low, 1972; Cassel and Nelson, 1985; Scott and Wood, 1989). In cultivated fields, seasonal changes in soil properties can be affected by tillage operations such as planting, cultivating and chiseling and are related to wheel traffic. This variability is called extrinsic variability (*Scott* and Wood, 1989).

These published studies have demonstrated that tillage affects both the magnitude and the variability of soil properties. Therefore, the objectives of this research were to determine and quantify the temporal changes in selected soil physical and chemical, properties of a loessial soil due to short- and long-term cropping. This work was conducted in an area in which rice, soybean and wheat are the dominant cropping systems.

MATERIALS AND METHODS

The study was conducted on the Fred Seidenstricker Farm, which is located south of Hazen in Prairie County, Arkansas. At the study site, the latitude is 34° N, the longitude is 91.5" W, and the average annual rainfall is 1338 mm. The soil is classified as a fine, montmorillonitic, thermic Typic Albaqualfs or a fine-silty, mixed, thermic Typic Glossaqualfs. The soil in the study location is an association of Crowley and Calhoun series and has poor 'internal drainage (SCS, 1981; Scott and Wood,

[1]Professor and former graduate assistant of agronomy and assistant professor of agricultural statistics, University of Arkansas, Fayetteville.

1989). The texture in the 0- to 0.15-m depth interval is silt loam.

Four adjacent fields were sampled on an approximately monthly basis (Fig. 1). These fields include a prairie and three fields that had mostly been in rotation of rice *(Oryza sativa)*, soybean *[Glycine max* (L.)] and wheat *(Triticum aestivum)* for 3, 14 and 32 years, respectively. During the 1989 growing season, the 3-years-in-cultivation field was fallowed but was disked in June and November. Soybeans were grown in the 14-year field from May to October 1989, and rice was grown in the 32-year field from April to September 1989. Wheat was grown in the 14- and 32-year fields from December 1989 until May 1990.

Soil samples were collected at 15-m intervals along a transect at depth intervals of 0 to 0.05 m and 0.05 to 0.10 m before the crops were planted during March 1989, during the growing season from May to September 1989 and after the crops were harvested on November 1989, December 1989, January 1990 and March 1990. Both undisturbed and disturbed samples were collected at each sampling time. Undisturbed soil samples were collected using steel cores having a diameter of 0.06 m and a height of 0.05 m. Soil physical properties determined on these undisturbed cores included saturated hydraulic conductivity (log Ksat), bulk density, soil porosity and soil water retention at pressures of 10, 20, 30, 50, 80, 100, 500 and 1500 kPa. Disturbed soil samples were'collected at 30- and 45-m intervals along the same transect and taken to the laboratory for analysis of particle size distribution, particle density, total carbon (TC) and pH in water and in $CaCl_2$.

For each soil property, exploratory statistics were performed to characterize the data at each field and depth interval. Computations were made of measures of central tendency and dispersion. Tests for normality were determined, and normal probability plots were constructed by field and depth interval averaged over sampling times.

Two statistical approaches were considered in order to quantify the temporal variability of the soil due to cropping. When the fields, depth interval and sampling times were fixed, the ANOVA was performed using a split-split plot in time. The computations were carried out using SAS's GLM procedure.

RESULTS AND DISCUSSION

Characterization of the Soil Properties

Selected properties of the soil profile in the prairie and 32-year fields were determined. The results for the first two depth intervals are presented in Table 1 and show that the texture was silt loam, the

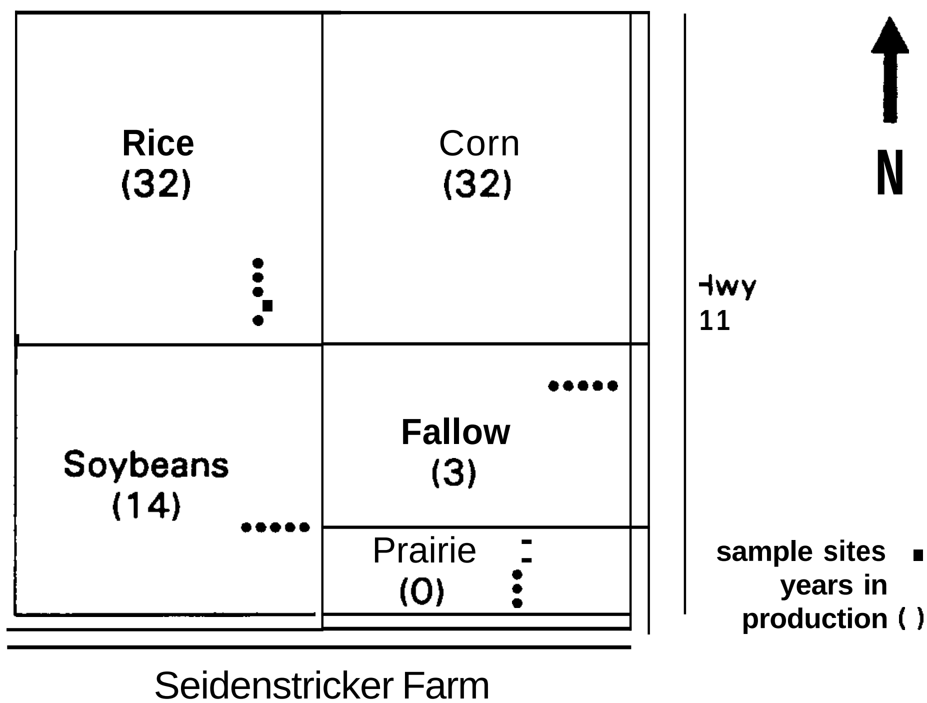

Fig. 1. Pictoriai representation of the four fields sampled on the Seidenstricker farm at Hazen, Arkansas.

TC content decreased with depth interval and time in cropping, and the pH of the prairie was more acid than that of the 32-year field. In general, the color of the prairie was darker in the surface than that of the 32-year field, a fact that can be attributed to its greater TC content. The particle density of the surface 10 cm was 2.62 and 2.66 g/cm^3 in the prairie and 32-year field, respectively.

Table 1. *Selected* soil properties of the prairie and 32-year field.

	Field			
	Prairie		32-year field	
Soil property	0-8 cm	8-15 cm	0-8 cm	8-15 cm
Particle size distribution				
% sand	16.8	16.4	14.0	15.8
% silt	67.3	67.4	70.2	68.6
% clay	15.9	15.2	15.8	15.6
Total carbon (g/kg)	21.3	12.6	11.2	7.6
pH (in water)	4.9	4.7	5.4	5.4
pH (in $CaCl_2$)	4.6	4.4	5.1	5.2

Temporal Variability of Selected Soil Properties

The ANOVA of each soil property involved three level factors (main, sub and sub-sub): cropping duration, depth interval and sampling time, respectively. The short-term variability of Log Ksat, bulk density and TC is shown in Fig. 2, 3 and 4, respectively. For all three soil properties the main effects of cropping time (field) and depth interval were highly significant. Sampling time was significant for Ksat, highly significant for bulk density and non-significant for TC. The interaction term of field x depth interval was highly significant for bulk density and TC. These results show that both short- and long-term variability are important considerations in evaluating the effects of cropping on soil properties.

Statistical Analyses

The means of each soil property for a given field (cropping duration) at each depth interval were computed for several soil properties taken over time. These results are presented in Table 2 and were the average of all of the samples taken from March 1989 to March 1990. In general, the lowest values of Ksat,

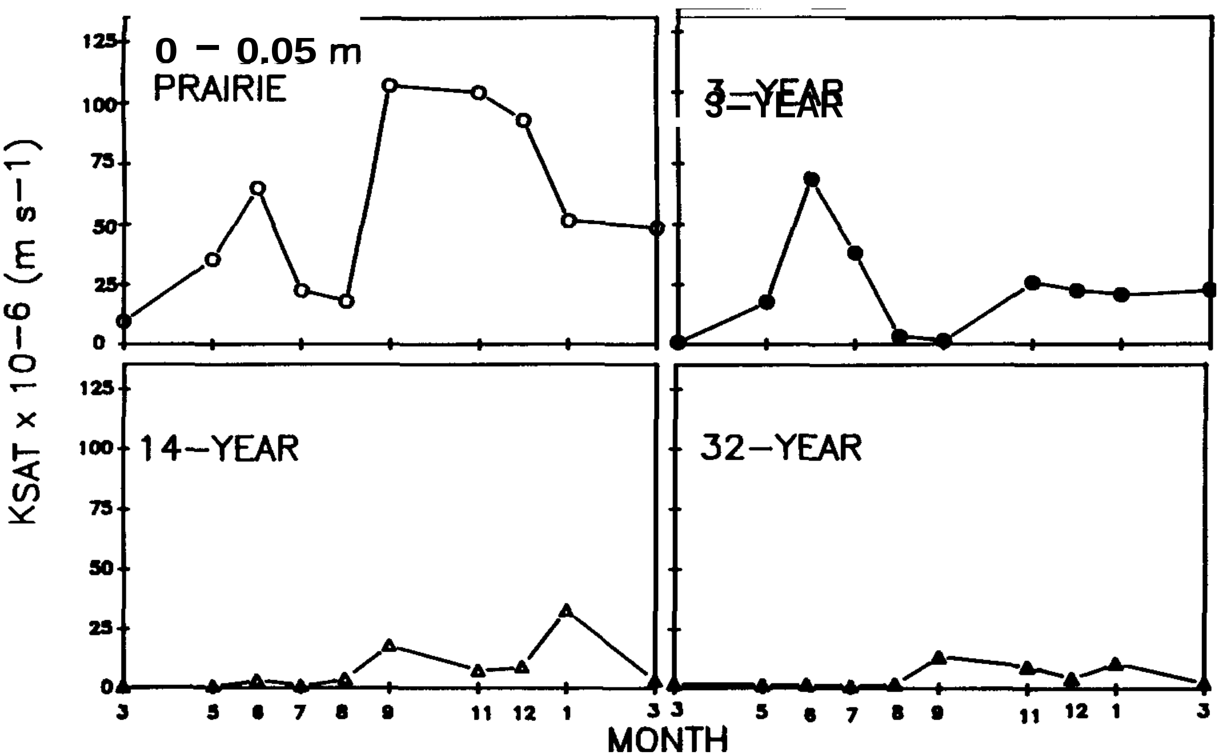

Fig. 2. Short-term variability of *the* saturated hydraulic conductivity in the four fields.

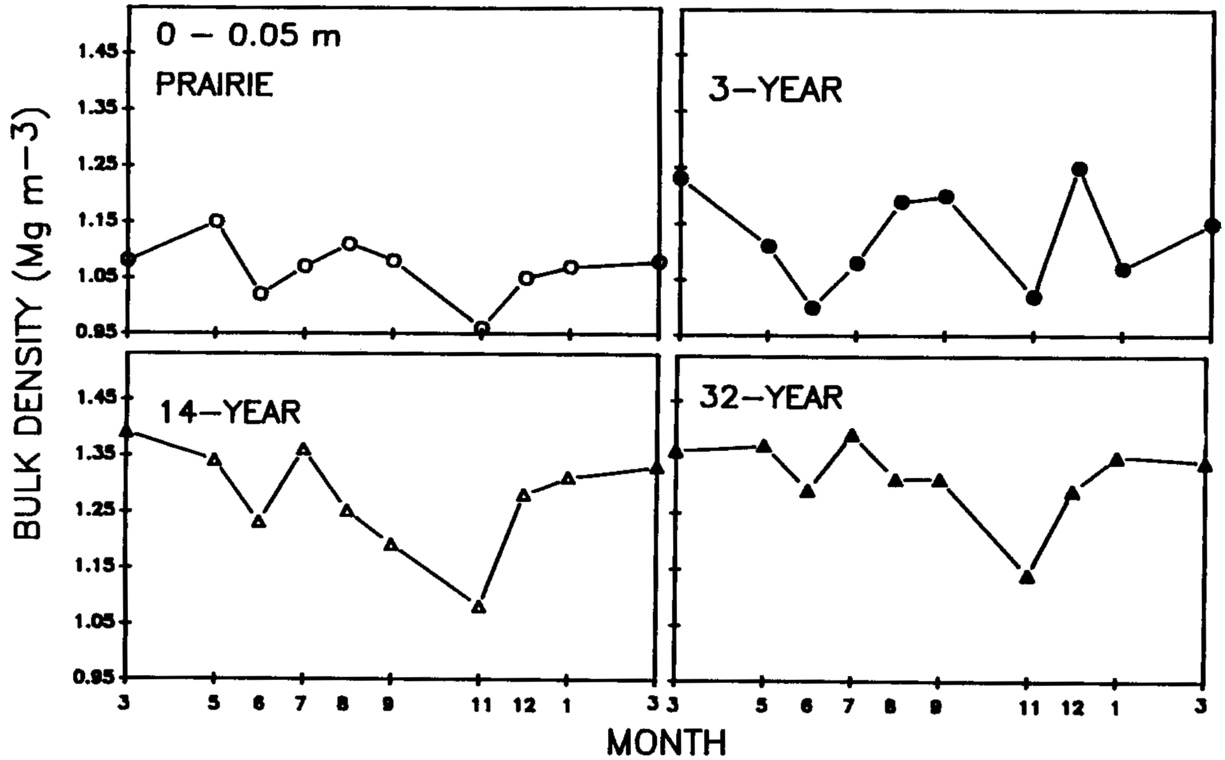

Fig. 3. Short-term variability of bulk density In the four fields.

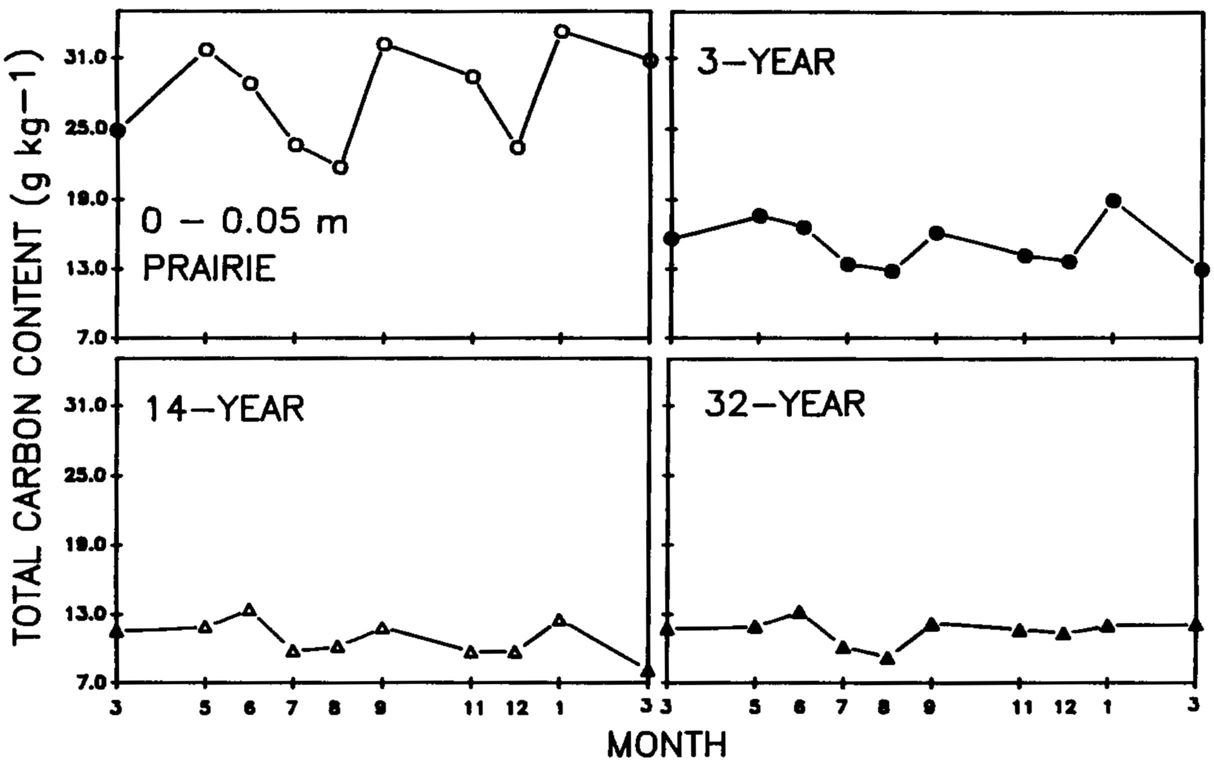

Fig. 4. Short-term variability of *total* carbon In the four fields.

Table 2. Summary statistics for Ksat by years In cropping and depth interval.

	Years in cropping							
	0		3		14		32	
Soil property	1'	2	1	2	1	2	1	2
Log Ksat(/ms x 10^5)	7.9	2.5	4.0	2.0	4.0	1.6	1.3	0.1
Bulk density(mg/m^3)	1.07	1.22	1.13	1.19	1.27	1.35	1.31	1.40
Total carbon(g/kg)	28.1	14.3	15.2	13.7	10.9	10.4	11.4	10.5
porosity(m^3/m^3)	0.59	0.53	0.57	0.54	0.52	0.49	0.51	0.48
pH in $CaCl_2$	4.3	4.1	5.2	5.1	5.4	5.5	5.1	5.2
10 kPa water ret.	0.443	0.425	0.400	0.408	0.381	0.376	0.397	0.393
1500 kPa water ret.	0.075	0.084	0.078	0.081	0.070	0.078	0.077	0.086

'Depth interval 1 = 0-5 cm; depth interval 2 = 5-10 cm.

TC and porosity were found in the 32-year field and in the 5- to 10-cm depth interval. The highest values of bulk density and pH in $CaCl_2$ were found in the 32-year field. From a practical view, decreases in Ksat may be beneficial in rice production but harmful in soybean production.

The means of TC in the four fields and two depth intervals were linearly regressed with the means of the soil parameters given in Table 2. The relationships are presented in Table 3. These results show that variations in TC alone could explain most of the variations in log Ksat, bulk density, porosity and 10 kPa water retention. The coefficients of determination associated with the variations of pH and water retained at 1500 kPa were low. Of interest is the fact that positive slopes were obtained for the relationships between TC and the dependent variables log Ksat, porosity and 10 kPa water retained, and this indicates that as TC increased, values of these parameters also increased. Negative slopes were obtained between TC and bulk density and pH in $CaCl_2$. The close relationship between TC and several of these soil properties suggests that losses of TC due to cropping in these soils were closely associated with the changes in the magnitude of the soil properties.

Table 3. Linear relationships between selected soil properties and total carbon (TC) content of the soil.

Dependent variable	Intercept	Slope	R^2
Log Ksat (x 10^5)	-2.245	0.361	0.778
Bulk density	1.465	-0.0156	0.670
Porosity	0.452	*0.0054*	0.704
pH in $CaCl_2$	5.81	-0.058	0.443
10 kPa WR	0.356	0.0032	0.731
1500 kPa WR	0.081	-0.0002	0.044

LITERATURE CITED

1. Baver, L.D., W.H. Gardner and W.R. Gardner. 1973. Soil physics. 4th Edition. New York John Wiley and Sons, Inc
2. Carter, M.R. 1988. Temporal variability of soil macroporosity h a fine sandy loam under moldboard ploughing and direct drilling. Soil Tillage Res. 12:37-51.
3. Cassel, D.K. 1983. Spatial and temporal variability of soil physical properties following tillage of Norfolk loamy sand. Soil Sci. Soc Am. J. 47:196-201.
4. Cassel, D.K., and L.A. Nelson. 1985. Spatial and temporal variability of soil physical properties following tillage of Norfolk loamy sand. Soil Sci. Soc Am. J. 47:196-201.
5. Gantzer, C.J., and G.R. Blake. 1978. Physical characteristics of Le Sueur clay loam soil following no-till and conventional tillage. Agron. J. 70:853-857.
6. Low, A.J. 1972. The effect of cultivation on the structure and other physical characteristics of grassland and arable soils (1945-1970). J. Soil Sci 23:363-380.
7. Scott, H.D., and L.S. Wood. 1989. Impact of crop production on the physical status of Typic Albaqualf. Soil Sci Am. J. 53:1819-1825.
8. Soil Conservation Service. 1981. Soil survey of Lonoke and Prairie counties. USDA-SCS and the University of Arkansas. p. 57-58.