Soil Changes Resulting from Cropping[1]

E. L. SKIDMORE, W. A. CARSTENSON, AND E. E. BANBURY[2]

ABSTRACT

The need to document further the changes in soil properties from various cropping systems and the uniqueness of a long-time cultivated field adjacent to buffalograss (*Buchloe dactyloides*) pasture prompted us to evaluate soil-property changes of a Keith silt loam (fine-silty, mixed, mesic, Aridic Argiustolls), characteristic of that pasture and field. In the fall of 1973, we broke the sod of the buffalograss pasture for analysis. Soil samples were obtained from the pasture (newly broken sod) and the adjacent cultivated field. The wet aggregates from the pasture were stabler as compared with the cultivated field for both flash and vacuum wetting. However, the dry aggregates from the cultivated field were slightly stabler than those from the pasture. The average clod densities were 1.7 and 1.3 g cm^{-3} from the tilled and pasture soils, respectively. The pasture soil was also much more permeable. The constant infiltration rate (after 6 hours of infiltration) averaged 0.95 and 0.13 cm hr^{-1} for pasture and cultivated soils, respectively. Because of the general deterioration of many of the physical properties of its soil, the cultivated field will require special management consideration.

Additional Index Words: tillage, soil structure, infiltration, organic matter.

SOIL'S PHYSICAL PROPERTIES generally deteriorate if a soil is intensively cultivated. Page and Willard (1946) found cultivation resulted in a loss of pore space and a corresponding increase in weight per unit-volume of soil. Other workers (van Bavel and Schaller, 1950; Wilson and Browning, 1945) observed decreased aggregation of soil under continuous corn. Olmstead (1946), who compared aggregation of soil from virgin buffalograss pasture with that of plots broken from virgin buffalograss (*Buchloe dactyloides*) prairie about 1902, found that in the surface-tilled zone the tilled plots had lost approximately 80% of their initial aggregation—a decrease sufficient to account for decreased crop yields. Harris et al. (1966) summarized their review of "Dynamics of Soil Aggregation" by reporting that a soil's aggregate status usually deteriorates rapidly if the soil is repeatedly cropped with annuals that supply little organic matter to the soil, require extensive cultivation, and provide minimal vegetative cover.

However, not all continuous row-cropping systems have deteriorated soil structure (Cary and Hayden, 1973.) Middleton (1952) reported tilling the soil at its most favorable moisture content usually will improve (or change very little) its structure because the aggregates formed from the joining of individual particles then will tend to counterbalance those disrupted by implement action. Harris et al. (1966) concluded grasses and perennial crops with extensive root systems, a continuous supply of readily decomposable organic matter, and effective protective coverage improve soil aggregation.

The change in soil properties from various cropping systems needs to be further documented. In this study, we evaluated the changes in chemical and physical properties of a Keith silt loam (fine-silty, mixed, mesic, Aridic Argiustolls) that may be attributable to cropping. The study was possible because a field cultivated for many years is adjacent to the buffalograss pasture being brought under cultivation.

METHODS AND PROCEDURE

The newly broken sod, cultivated for a few years about the turn of the century (from 1913 or 1914 until 1973), was in native pasture continuously. The main plant species (and approximate percentages) in the pasture included: 55% buffalograss, 20% western wheatgrass (*Agropyron smithii*), 17% red three-awn (*Aristida longiseta*), 5% tall dropseed (*Sporobolus*), 1% little barley (*Hordeum pusillum* Nutt.), and 2% miscellaneous weeds—prairieconeflower (*Ratibida* Raf.), gumweed (*Grindelia* Willd.), fetid marigold (*Dyssodia papposa* (Vent.) Hitchc.), and fireweed (*Epilobium angustifolium* L.).

In the fall of 1973, the sod was chiseled 83 cm on center, approximately 20 cm deep. After chiseling, the soil was prepared for plowing by disking twice—to level the area and break up sod clumps—and then plowed 15 cm deep and left for the winter. In early spring of 1974, a roller packer was used twice to level and prepare a seedbed for spring barley, planted in late February.

The cultivated field has been cropped for more than 60 years. Early cropping sequence included forage sorghum (*Sorghum bicolor* (L.) Moench.), wheat (*Triticum aestivum* L.), and wheat fallow. Starting in 1959 the sequence has been:

1959—summer-fallow
1960—fallowed wheat
1961—summer-fallow
1962—fallowed wheat
1963—summer-fallow
1964—fallowed grain sorghum
1965—summer-fallow
1966—fallowed Scout wheat
1967—summer-fallow
1968—fallowed Lancer wheat
1969—summer-fallow
1970—fallowed Shawnee wheat
1971—irrigated sugar beet
1972—nonirrigated spring barley
1973—irrigated corn

Soils from the field with a long-time cropping history and from the field previously in grass pasture will be referred to as "tilled" and "sod."

We obtained a composite (at least 10 subsamples) soil sample from both sod and tilled fields at 0- to 15-, 15- to 30-, and 30- to 60-cm depths. The samples were analyzed for chemical properties at the Kansas State Univ. Soil Testing Laboratory.

After about 10 kg of soil obtained from the plow layer of the cultivated and grassed sites were allowed to air-dry, we determined their dry-aggregate stability and size distribution by dry sieving according to Chepil's method (1951, 1952, 1958), using a sieve described by Lyles et al. (1970).

To determine wet-aggregate stability (of soil wetted both by vacuum and by direct immersion) of the 2.0- and 0.84-mm size fraction obtained from the dry sieving, we used the method described by Kemper (1965), except we used a 15.2-cm-diameter sieve and a 30-g soil sample. Our mechanical sieving machine lowered and raised the sieve holder through a distance of 2.7 cm 25 × each minute.

---

[1] Contribution from the Agric. Res. Serv., USDA, in cooperation with the Kansas Agric. Exp. Sta. Dept. of Agronomy Contribution no. 1461; Colby Branch Sta. no. 54. Paper presented before Div. S-6, Soil Sci. Soc. Am., Chicago, Ill. November 1974. Received 20 Jan. 1975. Approved 14 Mar. 1975.

[2] Soil Scientist and Engineering Technician, USDA, ARS, NCR, Manhattan, Kansas, and Superintendent, Colby Exp. Sta., Colby, Kansas.

Table 1—Chemical properties of the sod and tilled Keith soils, fall 1973

Depth	N	P	K	Zn	Fe	Cu	Mn	Organic matter	pH	Exchange capacity	Exchangeable sodium	Electrical conductivity saturated extract
cm	ppm							%		meq/100 g	%	mmhos/cm
						Sod						
0-15	1,210	14	613	0.72	11.4	0.5	20.6	3.0	7.5	13.7	2.22	0.42
15-30	770	6	750	0.35	11.2	0.6	11.0	1.5	7.9	13.6	2.21	0.30
30-60	800	13	838	0.31	6.4	0.6	8.2	1.7	7.8	14.9	1.71	0.50
						Tilled						
0-15	810	28	688	0.40	16.3	0.6	15.8	1.7	7.3	12.7	1.61	0.55
15-30	780	19	688	0.67	18.9	0.8	15.3	1.5	7.7	13.9	1.46	0.57
30-60	670	16	838	0.45	7.3	0.7	5.2	1.2	8.1	14.2	1.55	0.50

Modulus of rupture on the < 0.84-mm aggregates obtained from the dry sieving was determined by the method described by Reeve (1965).

Six samples from the plow layer and from below the plow layer (both field sites) were measured for hydraulic conductivity. The samples were obtained by pressing aluminum cylinders (15.2- by 7.0-cm) into the soil until soil filled all but the top 2 cm of the clyinder. Then the cylinder was removed from the soil and the soil trimmed from the bottom and taken to the laboratory, where its saturated hydraulic conductivity was measured by the falling-head method described by Klute (1965). After measuring saturated hydraulic conductivity, the soil was oven-dried and bulk density and particle-size distribution (Day, 1965) were determined.

On 10 April 1974, we evaluated the soil's water-intake characteristics, using five double-ring infiltrometers for each location and the method described by Bertrand (1965).

RESULTS AND DISCUSSION

Analyses revealed many of the chemical properties of the soil recently broken out of native grass pasture (sod) were similar to those of soil of the adjacent cultivated field (tilled) (Table 1). A few, however, reflected the difference in management history. The higher phosphorous content of the tilled soil was undoubtedly caused by phosphorus added as fertilizer. The slightly higher electrical conductivity of the tilled soil likely resulted from a slight accumulation of salt from irrigation water. Loss of organic matter and nitrogen in cultivated grassland has been well documented (Haas et al., 1957; Myers et al., 1943; Hobbs and Brown, 1957).

Several physical properties of the sod and tilled soils are compared in Table 2. When soil was wet, aggregates from the sod soil were stabler than those from the tilled soil. Difference in wet-aggregate stability between sod and tilled soil was greater in soils that had been flash wetted, or suddenly immersed in water (aggregation ratios of 0.33 and 0.04 for the sod and tilled, respectively), than in vacuum-wetted soils (aggregation ratios of 0.80 and 0.73 for the sod and tilled soils, respectively). Almost no tilled soil remained on the sieve after flash wetting and sieving for 5 minutes.

Wet sieving of the soil simulates forces that operate in the field to break down clods and aggregates. Immediately after cultivation, most soils contain an abundance of large pores. When the soil is wet under tension (simulated by vacuum wetting), the soil aggregates begin slaking and slumping, and thus filling many of the large pores. When the soil is initially dry, then wet suddenly as by flooding, the trapped air in the aggregates causes miniature explosions and accelerates aggregate breakdown. The more nearly complete breakdown of aggregates from the tilled than from the sod soil suggested that dense, unaggregated surface crusts likely form on flooded tilled soils.

Modulus-of-rupture determinations also suggested the more likelihood of surface crusting of the tilled than of the sod soil. Mean modulus of rupture of 15 samples was 15,300 and 62,800 dynes cm^{-2} for sod and tilled surfaces, respectively. The sod soil briquettes were fragile—11 of 15 broke in handling before force was applied; only 3 of 15 of the tilled soil briquettes broke before force was applied. The higher modulus of rupture for the tilled soil was significant at the 1% level (Table 2).

The mechanical analysis showed more clay and sand and less silt in the Ap of the tilled as compared with the sod soil. The Keith soil is usually classified as a silt loam, but proportions of sand, silt, and clay of the tilled soil would make it a silty clay loam (Table 2). Both silt loams and silty clay loams have sufficient clay and silt to form relatively stable dry aggregates.

Analyses showed the sod and tilled soils had stable dry aggregates with mean mechanical stabilities of 0.96 and 0.97, respectively. Mechanical stability of dry aggregates is a good index of a soil's ability to resist wind erosion; clods > 0.84 mm are considered nonerodible (Chepil, 1950, 1958). Since tilled and sod soils tested had > 70% of aggregates > 0.84 mm and a high degree of dry-aggregate stability, neither would likely present a serious wind-erosion problem.

The Ap horizon of the tilled soil was slightly denser than that of the sod (Table 2); the bulk densities of the A12 horizon of tilled and sod, however, were not significantly different. The clods formed in the Ap horizon were much denser in the tilled soil than in the sod 1.72 and 1.33 g/cm^3, respectively.

Electron micrographs of soil aggregates at low magnification (52 ×) showed more roots and cavities in the aggregates from the sod soil than in those from the tilled soil (Fig. 1A and 1B). But at high magnification (3,000 ×), the soils' microstructure seemed less different (Fig. 2), with

Table 2—Soil properties of the sod and tilled soils

Property	Units	Mean		Level of significance
		Sod	Tilled	
Wet aggregate stability				
Vacuum wetted	Dimensionless	0.80	0.73	0.05
Flash wetted	Dimensionless	0.33	0.04	0.01
Dry-aggregate stability	Dimensionless	0.96	0.97	0.01
Bulk density (Ap)	$g\ cm^{-3}$	1.29	1.38	0.10
Bulk density (A12)	$g\ cm^{-3}$	1.26	1.28	NS
Clod density	$g\ cm^{-3}$	1.33	1.71	0.01
Saturated hydraulic conductivity	$cm\ hr^{-1}$	2.32	0.02	0.05
Infiltration rate	$cm\ hr^{-1}$	0.95	0.13	0.05
Modulus of rupture	$dynes\ cm^{-2}$	1.53×10^4	6.28×10^4	0.01
Texture: sand	%	10.6	12.0	0.10
silt	%	64.2	55.8	0.01
clay	%	25.2	32.2	0.01

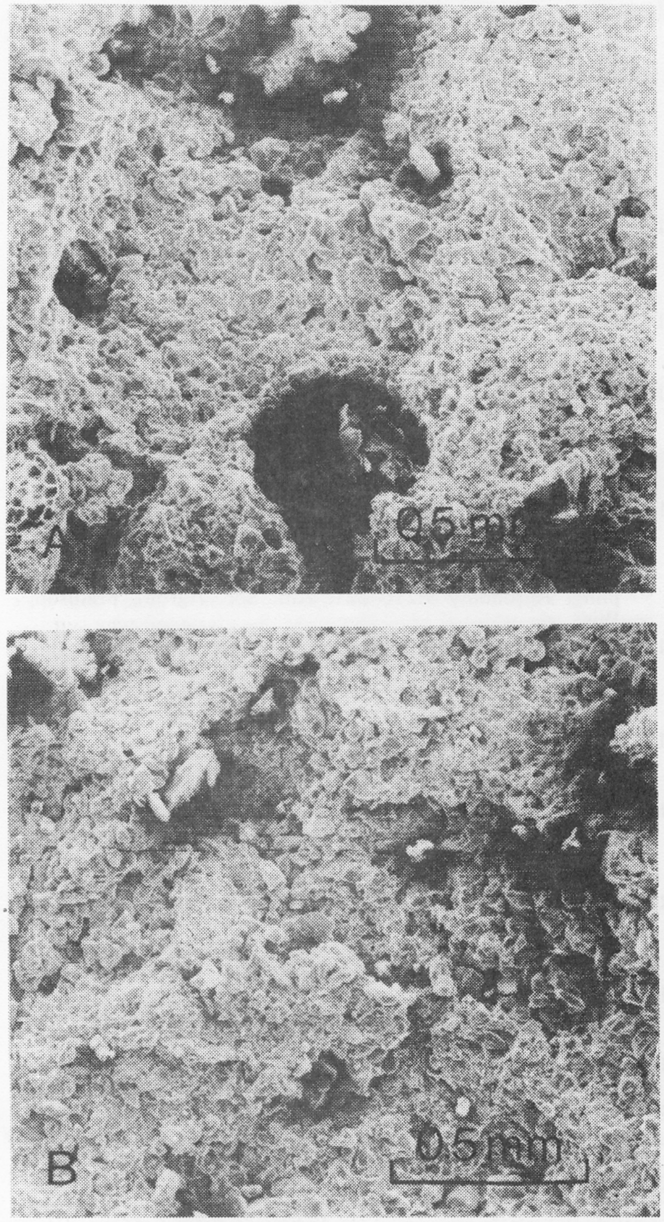

Fig. 1—Electron micrographs (52×) of sod (*A*) and tilled (*B*) soil from the Ap horizon.

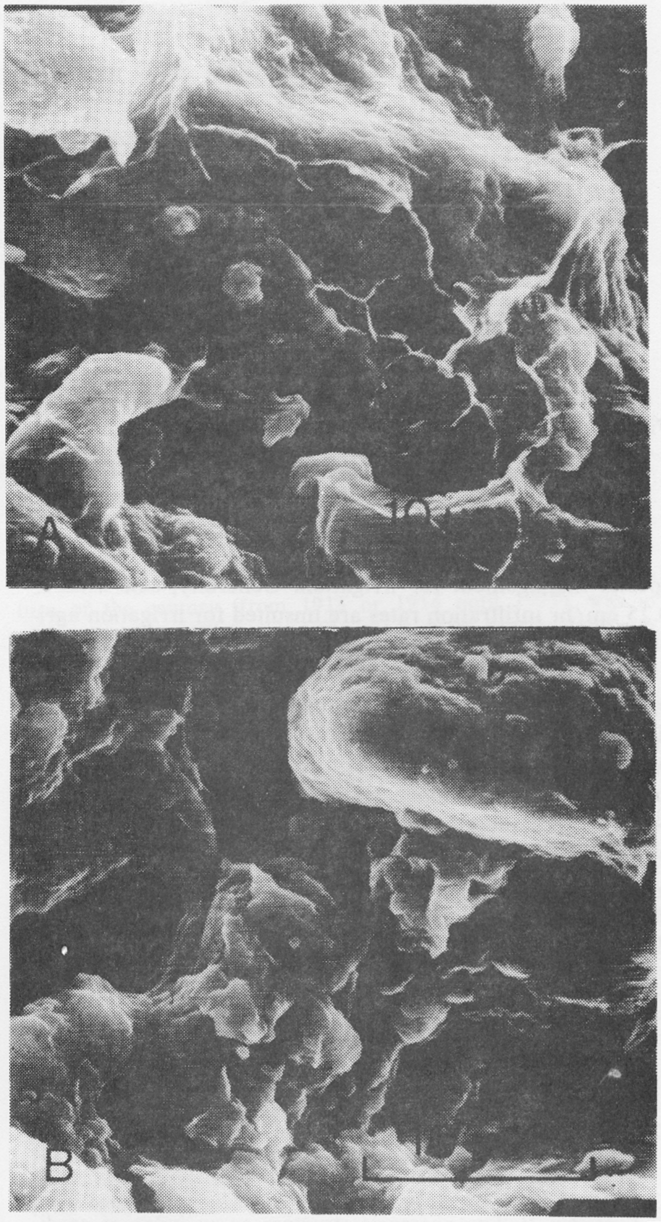

Fig. 2—Electron micrographs (3,000×) of sod (*A*) and tilled (*B*) soil from the Ap horizon.

the only apparent difference being the lines and coating appearance of the sod soils. We do not know what substance caused the lines or the coating. Low and Stuart (1974) found a similar difference between an old grassland soil and an arable soil of the same soil series. They suggested this as evidence of the presence of an adherent, presumably organic, matrix binding of the clay and other particles of the old grassland soil.

Because of its greater porosity and less-dense aggregates, the sod soil had higher and more variable saturated hydraulic conductivity and water infiltration rates than did the tilled (Table 2 and Fig. 3). Average constant infiltration rates after 6 hours of infiltration were 1.95 and 0.13 cm/hr for the sod and tilled soils, respectively. One of the five replications on the sod was extremely high (> 70 cm of water had infiltrated in 6 hours). But discarding extreme values, the average infiltration in the sod was still more than seven times (0.95 vs. 0.13 cm/hr) greater than in the tilled soil. Rauzi et al. (1968) reported for the second 30-minute period of 1-hour infiltration tests on rangeland of Keith silt loam in poor and excellent condition, water intake rates were 2.41 and 8.56 cm/hr, respectively.

Water conservation and runoff from rainfall and snowmelt are influenced by infiltration rate. If a rainstorm delivered 3.0 cm of water in a 6-hour period and the rain had entered the soil, according to the data of Fig. 3, at the end of the 6-hour period the sod and tilled soils would have absorbed 3.0 and 1.1 cm of water, respectively. If the same amount of rain had occurred in a 3-hour period, at the end of 3 hours all 3.0 cm of water would have entered the sod soil but only 0.72 cm in the tilled. In the less permeable soil, much more water runs off the field and less is conserved.

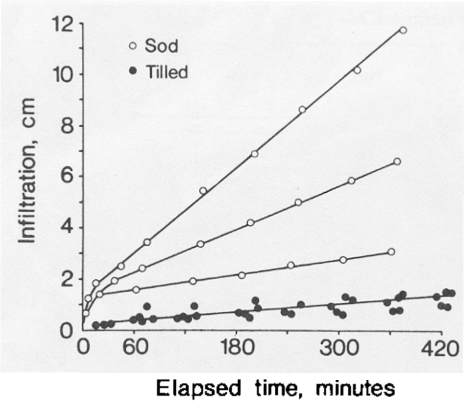

Fig. 3—Infiltration curves of sod and tilled Keith soil. The data for the fastest and slowest infiltration into the sod are not plotted, and only one curve is drawn through the data for all five replications of infiltration into the tilled soil.

Because of its slow water-intake rate, tilled soil needs special management for irrigation. Generally, soil with $<$ 0.25 cm/hr infiltration rates are unsuited for irrigation agriculture (Thorne and Peterson, 1954).

Henderson and Haise (1967) suggest two general approaches to the widespread problem of slow water intake: (i) improve soil structure, or (ii) alter water-management practices. To improve soil structure, they suggest adding soil amendments, using appropriate tillage and crop sequences, or sometimes adding organic matter and manure. Suggested water-management practices included irrigating more frequently, extending irrigation duration, increasing wetted area, and altering flow characteristics.

LITERATURE CITED

1. Bertrand, Anson. 1965. Rate of water intake in the field. *In* C. A. Black (ed.) Methods of soil analysis. Part 1. Physical and mineralogical properties, including statistics of measurement and sampling. Agronomy 9:202–207. Am. Soc. Agron., Madison, Wis.
2. Cary, J. W., and C. W. Hayden. 1973. Effects of crop rotations on the porosity and strength of the Portneuf silt loam soil. Agron. Abstracts, p. 121.
3. Chepil, W. S. 1950. Properties of soil which influence wind erosion: II. Dry aggregate structure as an index of erodibility. Soil Sci. 69:403–414.
4. Chepil, W. S. 1951. Properties of soil which influence wind erosion: V. Mechanical stability of structure. Soil Sci. 72: 465–478.
5. Chepil, W. S. 1952. Improved rotary sieve for measuring state and stability of dry soil structure. Soil Sci. Soc. Am. Proc. 16:113–117.
6. Chepil, W. S. 1958. Soil conditions that influence wind erosion. USDA Tech. Bull. 1185.
7. Day, Paul R. 1965. Particle fractionation and particle-size analysis. *In* C. A. Black (ed.) et al. Methods of soil analysis. Part 1. Physical and mineralogical properties, including statistics of measurement and sampling. Agronomy 9:545–567. Am. Soc. Agron., Madison, Wis.
8. Haas, H. J., C. E. Evans, and E. F. Miles. 1957. Nitrogen and carbon changes in Great Plains soil as influenced by cropping and soil treatments. USDA Tech. Bull. 1164.
9. Harris, R. F., G. Chesters, and O. N. Allen. 1966. Dynamics of soil aggregation. *In* A. G. Norman (ed.) Adv. Agron. 18:107–169.
10. Henderson, D. W., and Howard R. Haise. 1967. Control of water intake rates. *In* R. M. Hagen, H. R. Haise, and T. W. Edminster (ed.) Irrigation of agricultural lands. Agronomy 11:925–940. Am. Soc. Agron., Madison, Wis.
11. Hobbs, J. A., and P. L. Brown. 1957. Nitrogen and organic carbon changes in cultivated western Kansas soils. Kans. Agr. Exp. Sta. Tech. Bull. 89.
12. Kemper, W. D. 1965. Aggregate stability. *In* C. A. Black (ed.) et al. Methods of soil analsyis. Part 1. Physical and mineralogical properties, including statistics of measurement and sampling. Agronomy 9:511–519. Am. Soc. Agron., Madison, Wis.
13. Klute, A. 1965. Laboratory measurement of hydraulic conductivity of saturated soil. *In* C. A. Black (ed.) et al. Methods of soil analysis. Part 1. Physical and mineralogical properties, including statistics of measurement and sampling. Agronomy 9:210–221. Am. Soc. Agron., Madison, Wis.
14. Low, A. J., and P. R. Stuart. 1974. Micro-structural differences between arable and old grassland soils as shown in the scanning electron microscope. J. Soil Sci. 25:135–137 with 5 plates.
15. Lyles, Leon, J. D. Dickerson, and L. A. Disrud. 1970. Modified rotary sieve for improved accuracy. Soil Sci. 109(3):207–210.
16. Middleton, H. E. 1952. Modifying the physical properties of soil. *In* B. T. Shaw (ed.) Soil physical conditions and plant growth. Agronomy 2:24–41. Academic Press, New York.
17. Myers, H. E., A. L. Hallsted, J. B. Kuska, and H. J. Haas. 1943. Nitrogen and carbon changes in soils under low rainfall as influenced by cropping systems and soil treatment. Kans. Agr. Exp. Sta. Tech. Bull. 56.
18. Olmstead, L. B. 1946. The effect of long-time cropping systems and tillage practices upon soil aggregation at Hays, Kansas. Soil Sci. Soc. Am. Proc. 11:89–92.
19. Page, J. B., and C. J. Willard. 1946. Cropping systems and soil properties. Soil Sci. Soc. Am. Proc. 11:81–88.
20. Rauzi, Frank, C. L. Fly, and E. J. Dyksterhuis. 1968. Water intake on midcontinental rangelands as influenced by soil and plant cover. USDA Tech. Bull. 1390.
21. Reeve, R. C. 1965. Modulus of rupture. *In* C. A. Black (ed.) et al. Methods of soil analysis. Part 1. Physical and mineralogical properties, including statistics of measurement and sampling. Agronomy 9:466–476. Am. Soc. Agron., Madison, Wis.
22. Thorne, D. W., and H. B. Peterson. 1954. Irrigated soils, their fertility and management. The Blakeston Company, New York.
23. van Bavel, C. H. M., and F. W. Schaller. 1950. Soil aggregation, organic matter, and yields in a long-time experiment as affected by crop management. Soil Sci. Soc. Am. Proc. 15:399–404.
24. Wilson, H. A., and G. M. Browning. 1945. Soil aggregation, yields, runoff, and erosion as affected by cropping systems. Soil Sci. Soc. Am. Proc. 10:51–57.

Reprinted from the *Soil Science Society of America Proceedings*
Volume 39, no. 5, September-October 1975
677 South Segoe Rd., Madison, Wis. 53711 USA