SOIL STRUCTURE AS INFLUENCED BY SIMULATED TILLAGE

by

DAVID H. POWERS

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Approved by:

Edward Skidmore
Major Professor

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CHAPTER 1

SOIL STRUCTURE AS INFLUENCED BY SIMULATED TILLAGE

ABSTRACT

Soil is often intensively manipulated by tillage, equipment traffic, and preparation for laboratory analysis. Realizing that manipulated and fabricated soils have been and are being used in soil structure research, we used surface-soil and subsoil samples of cultivated and noncultivated Reading silt loam (fine, mixed, mesic, Typic Argiudolls) to evaluate the effects of simulated tillage on soil structure and to determine how well the structures of disturbed soils represent the structures of nondisturbed soils of similar composition. Soil cores 8.6 by 6 cm were formed after the following treatments had been applied: ultrasonically dispersed and freeze dried; crushed and passed through a 2 mm sieve; gently separated along planes of weakness while moist; and nondisturbed. The soil structural differences were evaluated by soil-water-characteristic curves, saturated-hydraulic conductivities, penetration resistances, compression indices, bulk densities, wet- and dry-aggregate stabilities, and scanning-electron-microscope photographs. The results show that the soil structures of fabricated, intensively or even mildly manipulated soils were significantly different from the nondisturbed soils of the same makeup. The greater the disturbance, the greater the differences between the nondisturbed and disturbed soils. The main differences were caused by the destruction of the cements and bonds between individual aggregates (mainly insoluble bonds) which create large, compound-unit (ped) structures.

INTRODUCTION

As preparations were completed to begin a soil-structure research project using fabricated soils made up of various mixtures of three soils (high sand, high silt, and high clay content), a question arose as to the reliability and/or relevance of fabricated or manipulated soils as they pertain to soil structural properties. We found that Dexter, et al. (14, 16, 17) and others had used synthetic or fabricated soils in studying soil structural properties and that Chen and Banin (10) had used a somewhat common preparation technique of drying, sieving to 2 mm, and compacting soil into containers in their soil-structure studies. We also realized that many soils that are tested in laboratories have been manipulated to some extent but this manipulation in testing has not been checked as to its accuracy in reflecting nondisturbed conditions.

Soil structural properties have been evaluated by various techniques. Many studies have looked at the aggregate stabilities (wet and dry) and aggregate distributions of noncultivated and cultivated, nondisturbed and disturbed soils (2, 3, 5-7, 11, 18, 20-22, 27, 29, 30, 32, 33, 35, 38, 39). Most of the tests were completed in the laboratory and the results showed that manipulation of soils in the field almost always weakened the soils' structural integrity. This weaker structure was observed in lower wet- and dry-aggregate stabilities (11, 20, 22, 27, 32, 33, 35, 39) higher bulk densities (3, 33) and lower porosities (3, 38). Other measurements that have evaluated soil structure have included compressions (14, 17, 26, 31), penetration resistances (9, 19, 31, 36, 37), saturated-hydraulic conductivities and permeabilities (4, 15, 28, 33, 38), and clod strengths (16, 33).

Our objective in this experiment was to evaluate the appropriateness of using fabricated soils (crushed, sieved, and mixed in various proportions) to evaluate the *influence of soil composition on* soil physical properties. To accomplish this objective, we evaluated the effects of simulated tillage on soil structure and determined how well the structure of disturbed soils represented the structure of nondisturbed soils of similar composition.

MATERIALS AND METHODS

Nondisturbed and disturbed samples of the Reading silt loam (a fine, mixed, mesic, Typic Argiudoll) from noncultivated prairie and an adjacent cultivated field were obtained for testing from the Konza Prairie Research Natural area located 16 kilometers south of Manhattan, Kansas. The noncultivated soil had never been cultivated and the cultivated soil between 1940 and 1970 was mainly used for grazing with legumes that were plowed under. Since 1970, conventional tillage with grain crops has been the practice.

The samples were taken from the surface soils (1- to 7-cm depth) and the subsoils (46- to 52-cm depth) on two occasions in July, 1979 and 1980. Five replications of nondisturbed soil-core samples (8.6 by 6 cm) were taken using a double cylinder, hammer-driven, soil-core sampler (4, 31). Several kilograms of soil were obtained with a shovel for the disturbed samples. Approximately a third of the disturbed sample was ultrasonically dispersed (sonicated) and then freeze dried. The remaining portions (two-thirds) either were crushed and passed through a 2-mm sieve or gently separated along planes of weakness while moist.

The disturbed soils were remolded into soil cores similar to the method of Chen (10). The soil was poured through a funnel into the cylinders and compacted by dropping the cylinders and soil 100 times through a distance of 1 cm. They were then soaked by capillarity and dried at 21°C.

The physical and structural differences among the treatments were measured by the following methods: bulk densities (soil-cylinder and/or clod densities); wet-(flash) and dry-(energy based and rotary sieve) aggregate stabilities; saturated-hydraulic conductivities (falling-head method); compression indices and penetration resistances at soil-water pressures of -300 mb and -1000 mb, and moisture-characteristic curves from 0 to -1 bar. Particle size analyses were also determined initially.

The soil-core and clod bulk densities of all of the initial samples were determined similar to the methods of Blake (4) except that we dried the cores at 21°C and used kerosene as the known-density liquid in testing the clods. Flash-wetting procedures as decribed by Kemper (23) were used to determine wet-aggregate stabilities.

Dry-aggregate stabilities of field-sampled soils were evaluated using the rotary-sieving technique described by Chepil (12). Soil samples were sieved four times and the fractional breakdown of the aggregates into smaller size ranges with successive sieving was calculated as a measure of dry-aggregate stability. This procedure requires a large sample and was not used on soils after treatment. The procedure described by Skidmore and Powers (Agronomy Abstracts, p. 192, 1980) was used for determining dry-aggregate stability of the treatment samples. Soil aggregates were crushed by diametrically loading between parallel plates of an Instron universal-testing instrument. The energy of crushing was determined and the surface area of aggregates after crushing was calculated to give energy of crushing per unit of new surface area (joules/m^2). Saturated-hydraulic conductivities were measured by falling-head methods similar to the methods outlined by Klute (26). Penetration resistances at soil-water pressures of -300 and -1000 mb were obtained by inserting simultaneously 2 brass cylindrical probes, 6 mm in diameter, into the soil at a rate of 2 mm/s for a distance of 6 mm. The resistances were measured with the Instron.

Compression indices were determined by the procedure of Larson et al. (26). Nine successive increments of load stress ranging from 0.1 to 25.0 kg/cm^2 were applied to soils in 8.6 x 6.0-cm brass cylinders. The soil sample rested on a porous ceramic plate. Replicates were run with the soil initially at two soil-water contents at soil-water pressures of -300 and -1000 mb. The volume of the sample was measured at each equilibrium point, and bulk densities were calculated. The slope of bulk density versus the logarithm of the applied stress of the linear portion of the curve (0.7 to 15 kg/cm^2 range) determined the compression index.

Soil clods of 0.5-1.0 cm diameter, from before and after compression, were mounted on aluminum biological stubs, and then coated with carbon and with a 60/40 gold palladium alloy. The prepared samples were examined with a ETEC U-1 scanning-electron microscope (SEM) at 2.5, 5.0, and 10.0 kV accelerating voltage. Photographs were taken at 15, 30, 120, 500, and 2000 x the original sample size.

Analyses of variance and least significant differences were determined at the 0.05 and 0.01 levels of confidence.

Part I covers the results when the nondisturbed, crush/sieve, and sonicated surface-soil treatments are compared and Part II covers the results when the nondisturbed and gently-separated surface-soil and subsoil treatments are compared.

RESULTS AND DISCUSSION

The dry-aggregate stabilities of the field sampled soils as determined by rotary sieve varied slightly with the season in which the samples were obtained. In all cases, the stabilities were high (above 0.93) for both cultivated and noncultivated soils.

PART I

The aggregates formed from the soil that had been previously crushed or dispersed were very weak unless compressed (Table 1). Their resistance to breaking into smaller units was low. Less than 0.2 joules of energy was required for each m^2 of newly exposed surface area on all samples. Whereas, before disruption 7.2 and 12.5 J/m^2 were required for the cultivated and noncultivated surface soils respectively. The wetting and drying cycles of the soil-packed cylinders did not reform firm aggregates.

Compression of the soils at 25 kg/cm^2 increased greatly the stability of the clods. The stability of the crush/sieve and sonicated samples both increased more than a hundred fold. After compression, the disturbed samples were two to three times more stable than the original disturbed samples but still only half to two-thirds as stable as the nondisturbed after compression.

The samples of the noncultivated, nondisturbed soil may be thought of as ped fragments. Considering the definition of peds and clods, we are to some extent comparing stabilities of clods and peds, (in this

TABLE 1
DRY-AGGREGATE STABILITIES

		Compressed (25 kg/cm^2)	
		Soil-Water Pressure	
Treatments	Noncompressed	-300 mb	-1000 mb
	---------------------- J/m^2	----------------------	----------------------
Cultivated			
Nondisturbed	7.18 ± 3.10**	33.54 ± 7.97**	30.46 ± 9.94**
Crush/sieve	0.17 ± 0.05	23.69 ± 3.46	22.35 ± 5.02
Sonicated	0.08 ± 0.01	20.41 ± 5.75	22.07 ± 3.91
Noncultivated			
Nondisturbed	12.52 ± 2.82**	40.25 ± 5.99**	38.97 ± 5.40**
Crush/sieve	0.05 ± 0.01	20.16 ± 4.76	22.21 ± 2.74
Sonicated	0.09 ± 0.01	19.49 ± 4.08	27.61 ± 6.87

**Significance at the 0.01 level

paper we are referring to both as aggregates). Peds are defined (1, 8, 35) as individual units of soil structure formed in natural processes whereas clods are coherent masses of soil formed or molded by the activity of man such as plowing or digging (13, 25).

The nondisturbed, cultivated sample with an aggregate stability of 7.2 J/m^2 behaved more like a ped than the crushed and sonicated and remolded samples with very weak structure.

Similarly with wet-aggregate stabilities, the samples that were physically subdivided into small fragments then formed into a larger unit for testing, were much less stable than those that were subdivided from the field-sampled aggregates (Table 2). In this case, the nondisturbed and crush/sieve are essentially the same. Samples were obtained from all three in the 1- to 2-mm diameter size range for wet-stability measurement. Structures of the sonicated samples were completely destroyed. Compound units were separated into primary particles and remolded, then 1 to 2 mm in diameter units were used in stability tests.

In all cases, the sonicated-treatment stabilities were much lower than either of the other two treatments but compression of the noncultivated soil doubled the wet-aggregate stabilities. Compression, in this case, seems to have helped remold these intensively disturbed soils. Compression of all of the nondisturbed and crush/sieve treatments except the noncultivated, nondisturbed treatment decreased the stabilities of the soils by 30 percent so that the crush/sieve treatments are shown to have about the same effect on soil stability as cultivation does. The noncultivated, nondisturbed soil treatment had a more stable aggregate structure after compression than any of the other treatments.

TABLE 2
WET-AGGREGATE STABILITIES

Treatments	Initial Sample	Noncompressed	Compressed (25 kg/cm^2) Soil-Water Pressure -300 mb	Compressed (25 kg/cm^2) Soil-Water Pressure -1000 mb
	g/g			
Cultivated				
Nondisturbed	0.48 (a)‡	0.48	0.30	0.28
Crush/sieve	0.76 ± 0.11(b)	0.66	0.34	0.29
Sonicated	0.05 ± 0.01(c)	0.15	0.15	0.13
Noncultivated				
Nondisturbed	0.86 ± 0.05(a)	0.85	0.81	0.75
Crush/sieve	0.95 ± 0.01(b)	0.94	0.67	0.61
Sonicated	0.18 ± 0.02(c)	0.15	0.30	0.32

‡ Values followed by a common letter in each column are not significantly different at the 0.05 level.

Compression of the samples increased dry-aggregate stability and decreased wet-aggregate stability. This forcing of the particles into closer proximity to each other created a compact unit more resistant in a dry state to disruption from physical forces. Compression also broke bonds that had formed during natural aggregation and which were more resistant to the disruptive action of differential swelling and entrapped-air exploding of water-submerged aggregates.

Disturbing soils (crush/sieve and sonicated treatments) caused significantly different soil-water-characteristic curves in comparison to the nondisturbed treatments (Fig. 1 and 2). The general trend was that the soils which were disturbed the most (sonicated), had the highest volumetric water content at each of the soil-water pressures between -10 and -100 mb and the least disturbed soils (nondisturbed) had the lowest water-content values in this range. In the -100 to -1000 mb range, all of the disturbed treatments fell off in water content until they had less moisture per soil-water pressure than did the nondisturbed treatments. The cultivated soils also had higher water contents at each soil-water pressure than the noncultivated did, which shows the same general trend in cultivation and manipulation effects. These higher water contents for disturbed soils might be due to their large aggregate surface areas to attract more water than the nondisturbed and their early drainage due to their larger percentage of small pore spaces which drain out at pressures between -10 and -100 mb. The nondisturbed treatments seemed to have a more uniform distribution of even smaller pore spaces. The sonicated treatments, as expected, had the highest water contents at each soil-water pressure and the poorest structure followed by the crush/sieve and then the nondisturbed treatments which had increasingly lower water contents and better structures. These

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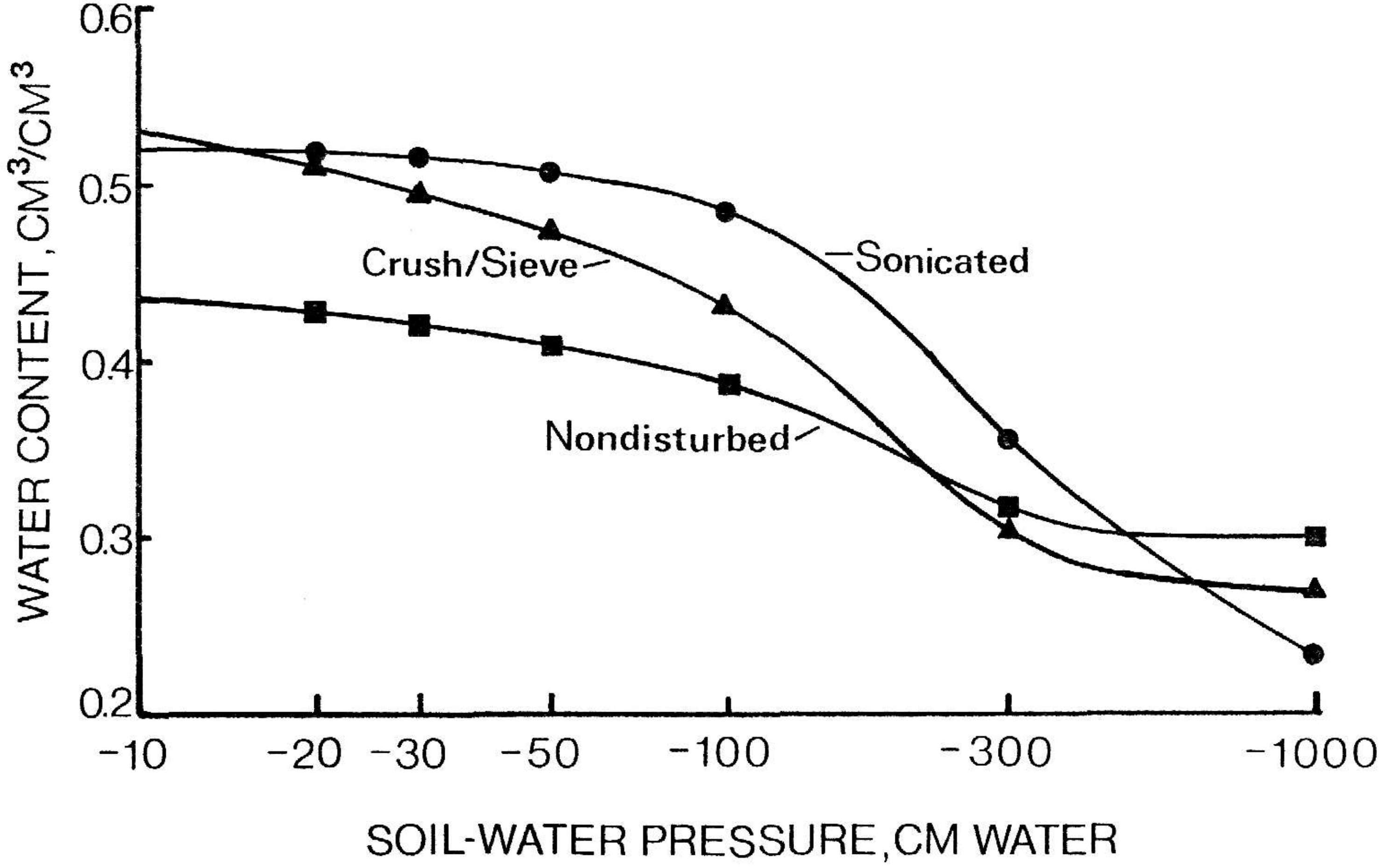


Fig. 1 Soil-water characteristic of cultivated Reading silt loam surface soils for indicated treatments.

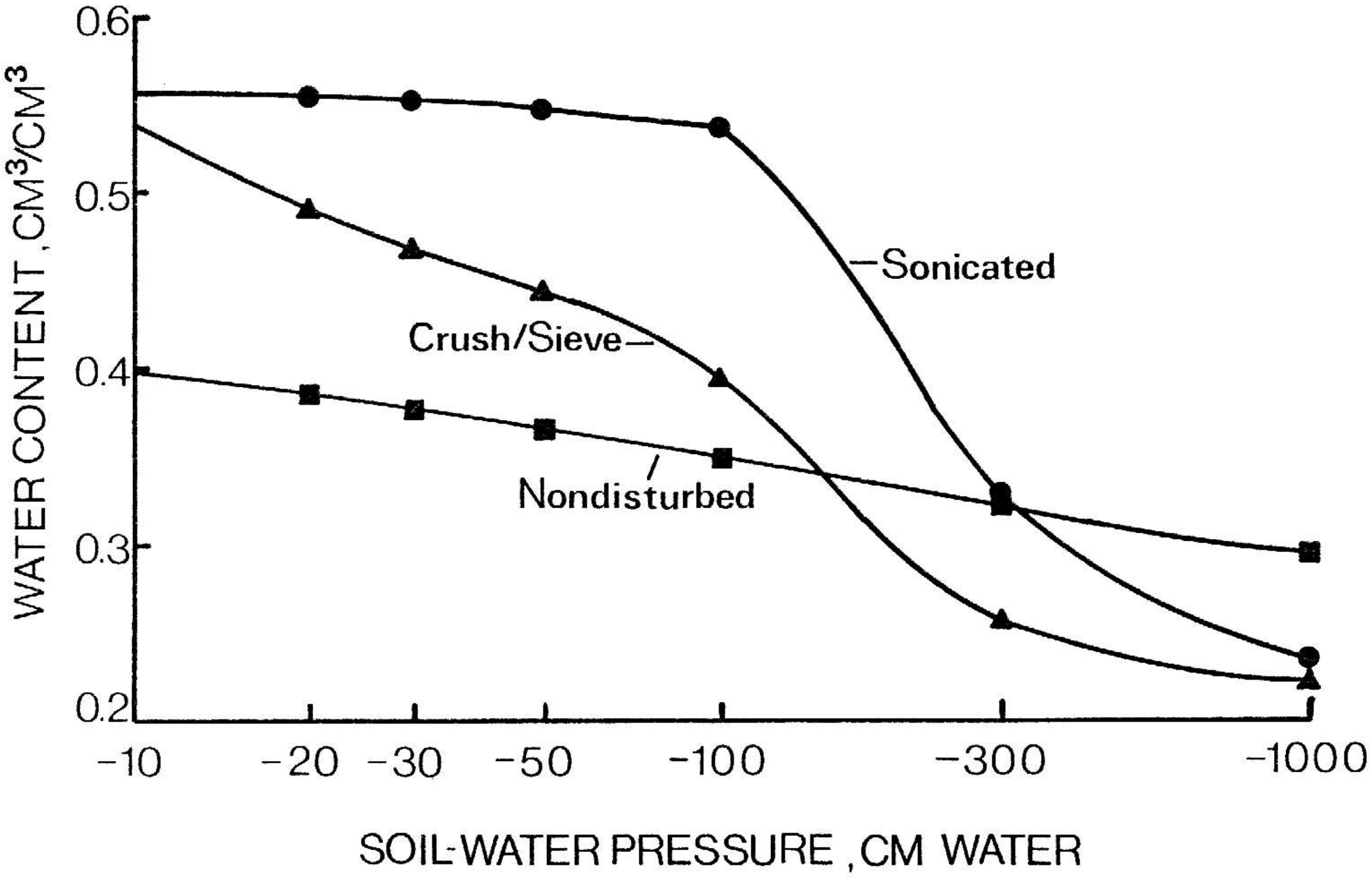


Fig. 2 Soil-water characteristic of noncultivated Reading silt loam surface soils for indicated treaments.

soil-moisture-characteristic-curve results showed that good, low variability soil-structure information can be determined using this test.

Saturated-hydraulic conductivities tended to vary with the bulk density of the soils but did show the effects of disturbing soils (Table 3). For both the noncultivated and cultivated soils, the disturbed treatments had significantly lower bulk densities than did the nondisturbed treatments due to remolding of the disturbed soils. In all of the treatments, the noncultivated soils had higher saturated-hydraulic-conductivity values than did the corresponding cultivated treatments, thus showing the degrading effects of cultivation. Sonication of both soils caused their conductivities to be significantly lower than those for the other treatments except when compared to the cultivated, nondisturbed treatment which was much lower. When bulk densities are accounted for, we could conclude that sonication and cultivation have similar degrading effects upon soil-water conductivities and structures. Crushing, sieving, and remolding soils significantly increased the conductivities of the cultivated soils probably due to the percentage of larger pore spaces between individual aggregates. This correlates well with reports of increased permeabilities of field soils after cultivation.

Initially, the bulk densities of the nondisturbed were higher than the disturbed (crush/sieve and sonicated) treatments. After compression, there was little difference between the bulk densities of the treatments involved (Table 4). There were, however, some important trends in that in all cases, the crush/sieve and sonicated treatments went from the lowest bulk densities before compression to the highest bulk densities after compression. This shows the greater

TABLE 3
SATURATED-HYDRAULIC CONDUCTIVITIES

Treatments	Falling-Head Conductivity	Initial Bulk Density
	cm/s x 1000	g/cm^3
Cultivated		
Nondisturbed	0.01 ± 0.001(a)‡	1.42 ± 0.03(a)
Crush/sieve	1.98 ± 0.13(b)	1.22 ± 0.01(b)
Sonicated	0.13 ± 0.01(c)	1.12 ± 0.01(c)
Noncultivated		
Nondisturbed	3.67 ± 0.50(a)	1.12 ± 0.03(a)
Crush/sieve	6.25 ± 2.04(a)	1.01 ± 0.02(b)
Sonicated	0.23 ± 0.12(b)	1.05 ± 0.01(c)

‡ Values followed by a common letter in each column are not significantly different at the 0.05 level.

TABLE 4
COMPRESSION INDICES, C, AND FINAL BULK DENSITIES FROM INCREMENT LOADING TO 25 kg/cm^2

Treatments	Initial Soil-Water Pressure			
	-300 mb		-1000 mb	
	C	g/cm^3	C	g/cm^3
Cultivated				
Nondisturbed	0.31	1.76 ± 0.02(a)‡	0.28	1.73 ± 0.03(a)
Crush/sieve	0.33	1.81 ± 0.02(a)	0.35	1.88 ± 0.02(a)
Sonicated	0.37	1.86 ± 0.05(a)	0.35	1.76 ± 0.04(a)
Noncultivated				
Nondisturbed	0.29	1.61 ± 0.01(a)	0.22	1.62 ± 0.03(a)
Crush/sieve	0.36	1.68 ± 0.02(a)	0.33	1.57 ± 0.02(a)
Sonicated	0.39	1.66 ± 0.01(a)	0.38	1.85 ± 0.13(a)

‡ Values followed by a common letter in each column are not significantly different at the 0.05 level.

compressibility and weaker structure of these treatments and correlates well with the compression results (Table 4). The larger the value of the compression index, the steeper the slope and more compressible the soil than the smaller values. In each case, the nondisturbed-soil treatments were less compressible than the crush/sieve or sonicated treatments as indicated previously by the bulk-density results. The noncultivated, nondisturbed treatment was less compressible than its cultivated counterpart but the crush/sieve treatments for both soils were similar. These crush/sieve results show that the manipulation and compression effects were greater on the noncultivated soils than on the cultivated soils (Table 4). The sonicated soils had the highest compression indices, the steepest slopes, the most compressible soils, and the weakest structures, between and within the aggregates and particles. These compression and bulk-density measurements for soil structure are informative and seem to be reliable tests of soil-structure differences. Equaling out the bulk densities of the initial soils after treatment, would be one important step toward making the bulk-density values more beneficial.

The scanning-electron-microscope photographs verified the results of the other experiments (Fig. 3-5). The noncultivated, nondisturbed surface soil (Fig. 3A) had individual particles and aggregates bonded together into large compound units (peds) separated by cleavage planes. The structure of the noncultivated, crush/sieve and sonicated treatments (Fig. 3B-C) were made up mainly of individual particles, with some aggregates, that weren't bonded together and which had larger spaces between particles. The noncultivated, crush/sieve treatment (Fig. 3B) did have some larger aggregates where the bonding between particles hadn't been broken but these aggregates were fewer in number and smaller

Fig. 3 Scanning-electron-microscope (S.E.M.) photographs at 30x of noncompressed (A-C) and compressed (D-F) Reading silt loam noncultivated surface soils for indicated treatments.

Noncultivated, noncompressed

A-nondisturbed

B-crush/sieve

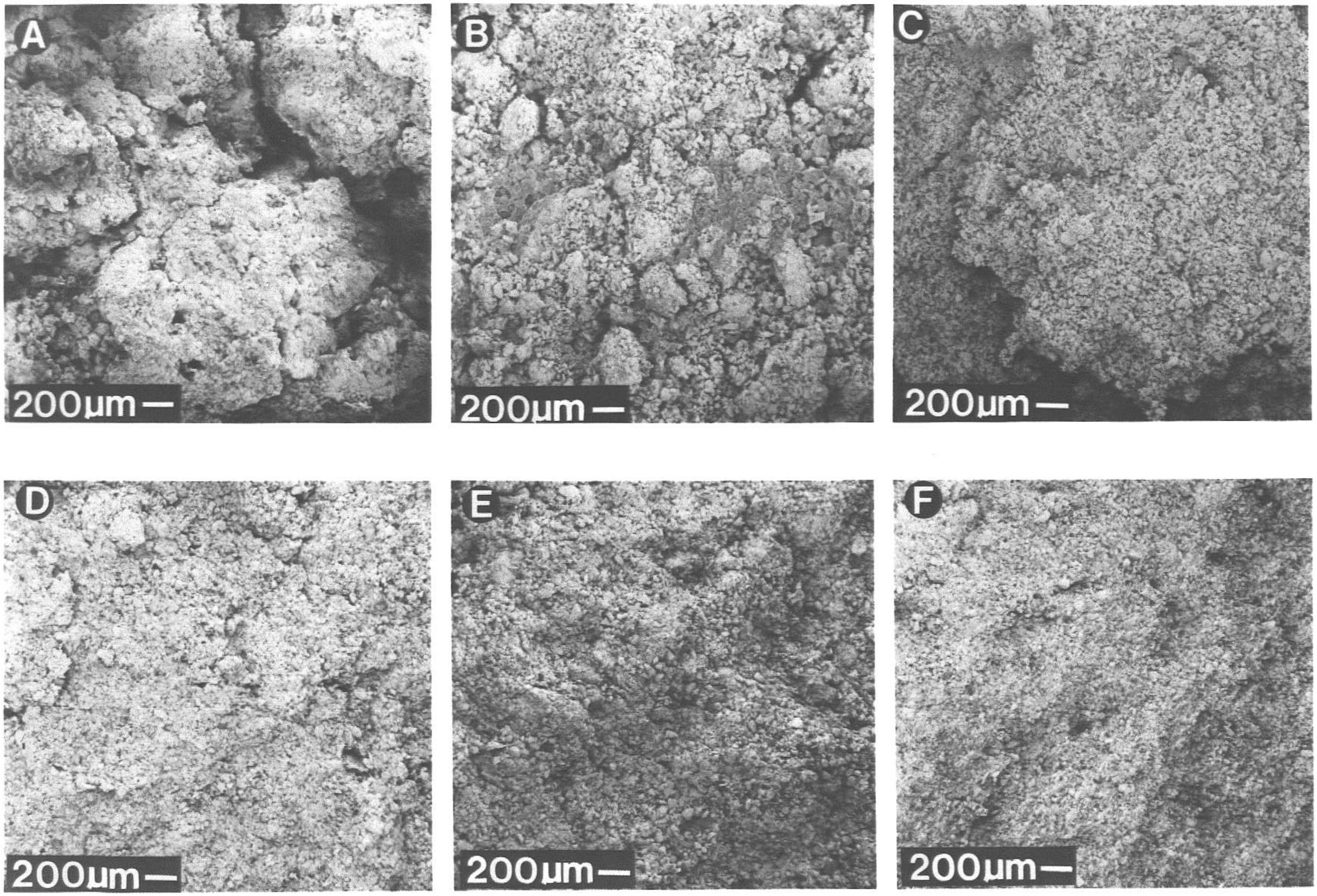
C-sonicated

Noncultivated, compressed

D-nondisturbed

E-crush/sieve

F-sonicated


A
200µm
B
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C
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D
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E
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F
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in size. After compression (Fig. 3D-F), the size of the individual particles and clods looked similar except that the noncultivated, nondisturbed (Fig. 3D) appeared to have more bonding between aggregates than the two disturbed treatments. This shows why the dry-aggregate stabilities of the noncultivated-soil treatments were higher before and after compression and also represents what happened to the cultivated treatments also.

At 500x (Fig. 4 and 5), the individual particles were about the same size but the noticeable difference was that these particles were bonded together by insoluble (probably organic) cements in the nondisturbed treatments (Fig. 4A and 5A) and looked like talus deposits of individual particles in the disturbed treatments (Fig. 4B-C and 5B-C). There were still signs of the cements present on the particles of the disturbed treatments (Fig. 4B-C and 5B-C) but they weren't cementing particles together as is especially well depicted in the noncultivated, nondisturbed treatment (Fig. 5A). These insoluble bonds or lack of them show why the dry aggregates of the nondisturbed treatments were more stable than the disturbed initially, and after compression. The dry aggregates from the noncultivated, nondisturbed soil (12.5) were more stable and stronger initially than were the aggregates from the cultivated, nondisturbed soil (7.2) because of a larger volume of these bonds. After compression of these soils (Fig. 4D-F and 5D-F), the aggregates and bonds between aggregates were broken and particles were welded together into clods with soluble clay bonds and the remaining organic bonds (Fig. 4D-F and 5D-F). There seemed to be little difference between the treatments after compression (Fig. 4D-F and 5D-F) but the nondisturbed treatments (Fig. 4D and 5D) still had more insoluble bonds than the disturbed even though their bonds had been

Fig. 4 Scanning-electron microscope (S.E.M.) photographs at 500x of noncompressed (A-C) and compressed (D-F) Reading silt loam cultivated Surface soils for indicated treatments.

Cultivated, noncompressed

- A-nondisturbed
- B-crush/sieve
- C-sonicated

Cultivated, compressed

- D-nondisturbed
- E-crush/sieve
- F-sonicated

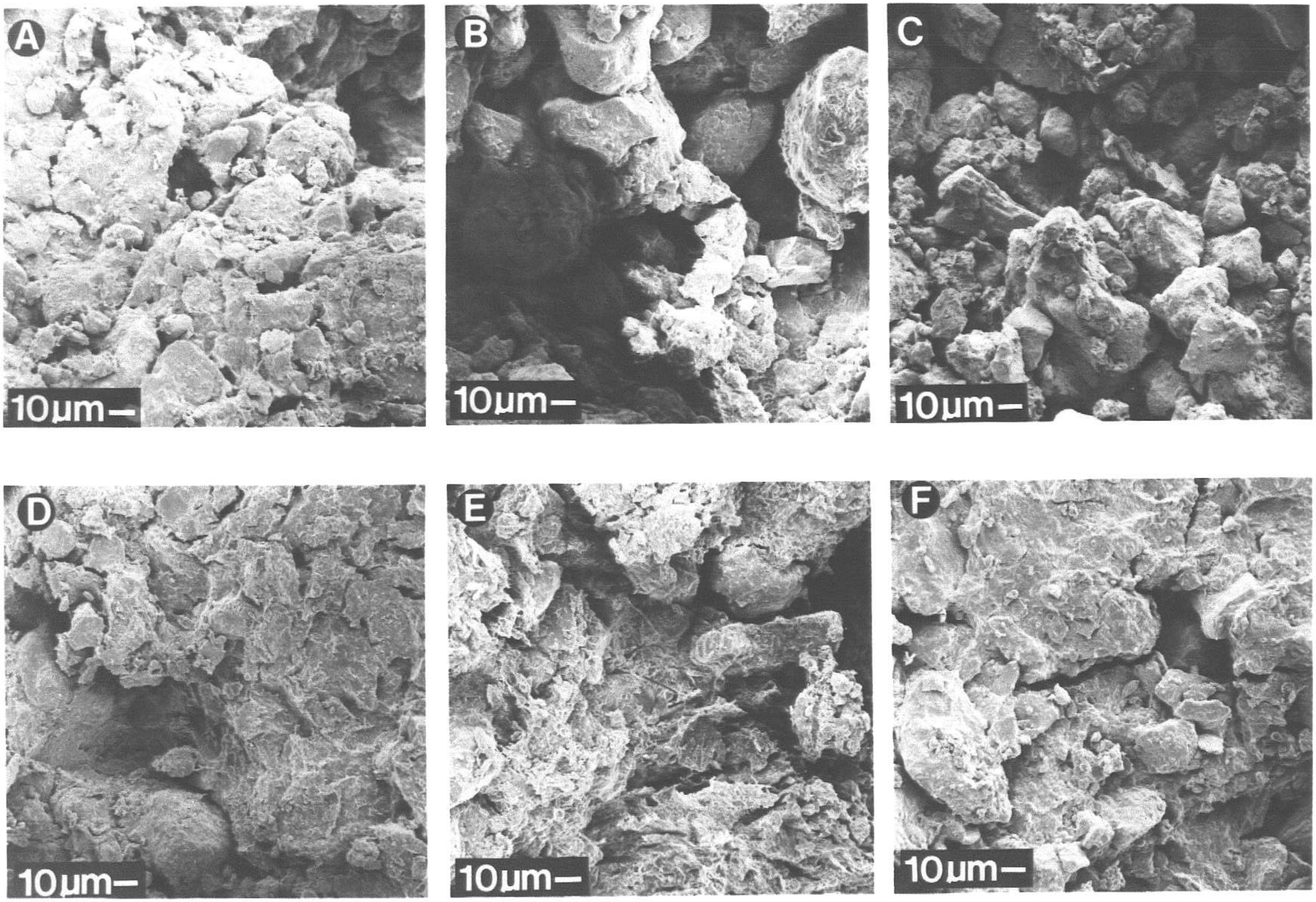
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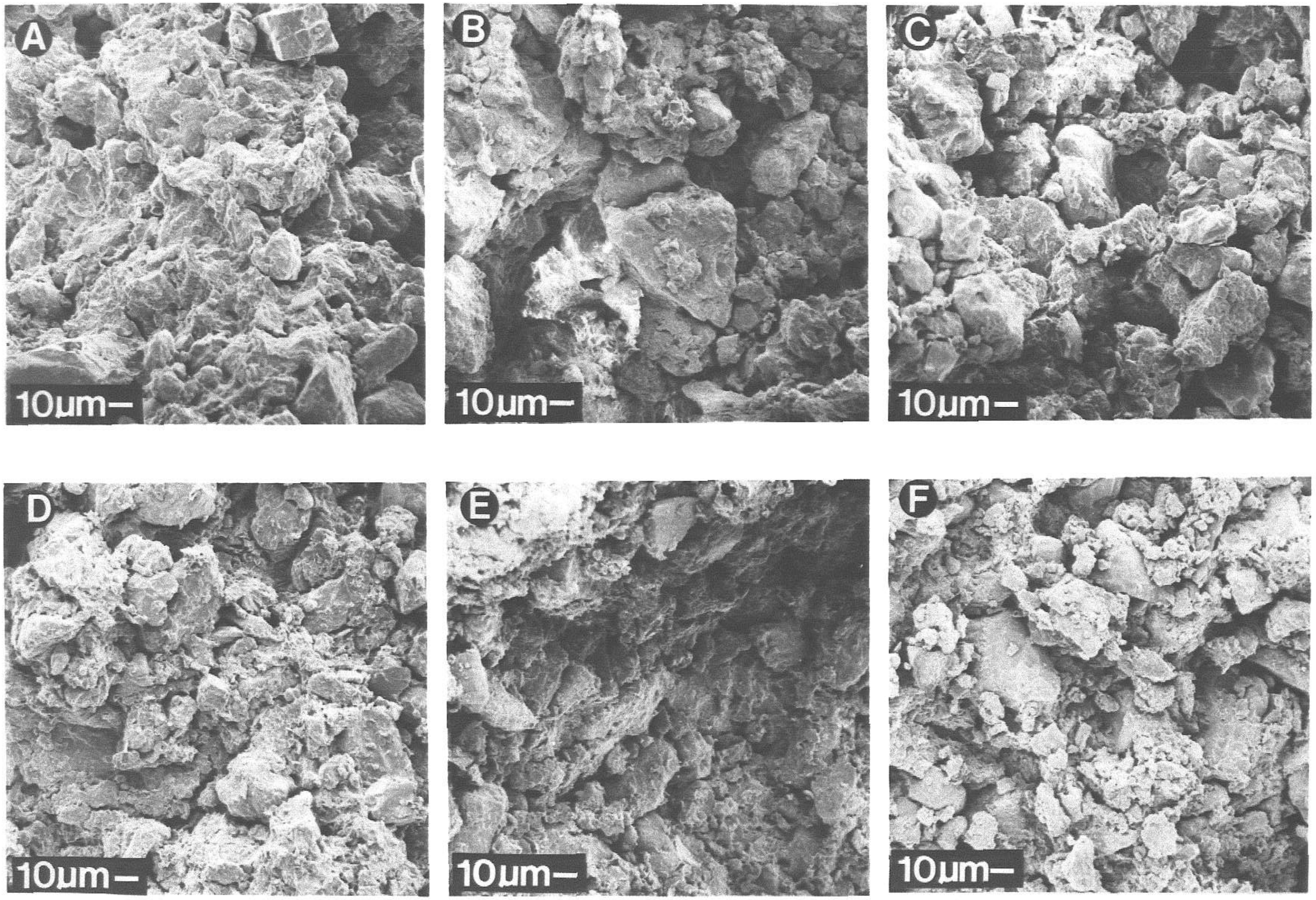
Fig. 5 Scanning-electron-microscope (S.E.M.) photographs at 500x of noncompressed (A-C) and compressed (D-F) Reading silt loam noncultivated surface soils for indicated treatments.

Noncultivated, noncompressed

- A-nondisturbed
- B-crush/sieve
- C-sonicated

Noncultivated, compressed

- D-nondisturbed
- E-crush/sieve
- F-sonicated


A
10µm—
B
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C
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D
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E
10µm—
F
10µm—

noticeably broken (Fig. 5A, D).

Compression welding of the soil particles together into clods with clay and other soluble bonds probably caused the large increase in the dry-aggregate stabilities of each treatment (Table 1). Compression bonding also caused the breaking of the insoluble, inter-aggregate bonds of the large structures causing the new soluble-bonded clods to collapse during wet-aggregate-stability testing (Table 2). The breaking of the insoluble bonds within aggregates 1-2 mm in size didn't show up as much before compression because only the large compound-unit structures had been destroyed and not the smaller individual-aggregate structures (Table 2). The larger void spaces between particles and aggregates and the lack of bonding between these, tells us why the disturbed soils had higher saturated-hydraulic conductivities (Table 3) and why they lost their water at lower soil-water pressures than the nondisturbed soils (Fig. 1-2). This lack of good bonding together of aggregates and of good orderly structure is the main reason the disturbed soils were the most compressible (Table 4).

Similar destructive, structural features were evident when the noncultivated and cultivated, nondisturbed soils were compared for cultivation effects (Fig. 4A, D and 5A, D).

PART II

Energy-based dry-aggregate stabilities comparing the gently-separated with the other treatments (Table 5) reflected similar trends as in part I. The stabilities were weak (0.06 to 0.5 J/m^2) and similar to the other disturbed treatments initially and increased in stability several hundred fold after compression. The compressed, gently-separated, surface-soil-treatment stabilities were 1 to 8 J/m^2 higher than the other disturbed (crush/sieve and sonicated) treatments after compression. This least of all disturbed treatments probably still has the most insoluble bonding between aggregates left of all of the disturbed treatments. These gently-separated, disturbed-treatment stabilities most closely represented the nondisturbed, surface-soil treatments after compression especially when the cultivated surface soils were compared. More insoluble, inter-aggregate bonding of clods apparently still exists in the gently-separated treatments. The compressed, gently-separated-treatment subsoils most closely represented the nondisturbed soils of all of the soil treatments. They were virtually the same due to a smaller amount of insoluble (organic) bonds and a larger amount of soluble, inter-aggregate (clay) bonds to begin with. There weren't as many insoluble bonds to break so manipulation did not affect the nondisturbed subsoils as much. The noncultivated subsoils were more stable than the cultivated subsoils by 5 to 8 J/m^2 and the subsoils were more stable than the surface soils by 7 to 20 J/m^2. This again emphasizes how important those insoluble bonds are to individual- and compound-unit aggregate structures and how the soluble bonds are important in clod structure.

TABLE 5
DRY-AGGREGATE STABILITIES

Treatments	Noncompressed	Compressed (25 kg/cm^2) Soil-Water Pressure -300 mb	-1000 mb
	J/m^2		
		Surface Soils	
Cultivated			
Nondisturbed	7.18 ± 3.10(a)‡	33.54 ± 7.97(a)	30.46 ± 9.94(a)
Gently-separated	0.27 ± 0.05(b)	28.30 ± 7.07(ab)	40.15 ± 8.07(b)
Crush/sieve	0.17 ± 0.05(b)	23.69 ± 3.46(bc)	22.35 ± 5.02(c)
Sonicated	0.08 ± 0.01(b)	20.41 ± 5.75(c)	22.07 ± 3.91(c)
Noncultivated			
Nondisturbed	12.52 ± 2.82(a)	40.25 ± 5.99(a)	38.97 ± 5.40(a)
Gently-separated	0.08 ± 0.02(b)	27.42 ± 3.96(b)	28.32 ± 3.13(b)
Crush/sieve	0.05 ± 0.01(b)	20.16 ± 4.76(c)	22.21 ± 2.74(c)
Sonicated	0.09 ± 0.02(b)	19.49 ± 4.08(c)	27.61 ± 6.87(b)
		Subsoils	
Cultivated			
Nondisturbed	20.97 ± 3.04(a)	48.03 ± 5.57(a)	40.76 ± 8.12(a)
Gently-separated	0.06 ± 0.02(b)	47.55 ± 9.81(a)	49.43 ± 12.73(a)
Noncultivated			
Nondisturbed	36.72 ± 12.42(a)	55.33 ± 14.10(a)	55.35 ± 21.63(a)
Gently-separated	0.48 ± 0.22(b)	34.22 ± 7.61(b)	50.82 ± 11.17(a)

‡ Values followed by a common letter in each column are not significantly different at the 0.05 level.

Gently-separated treatment, wet-aggregate stabilities (Table 6) were initially higher than the other disturbed-treatment stabilities but differences were small between the nondisturbed, gently-separated, and crush/sieve, noncompressed-treatment stabilities. These initial and noncompressed stabilities varied somewhat with the season in which they were sampled as well as with the treatment applied. All of the wet-aggregate stabilities except the sonicated-soil stabilities were initially very high ranging from 0.48 to 0.95 g/g. After compression, all of the treatment stabilities fell off but the most significant decrease occurred in the cultivated surface soils and all subsoils. The gently-separated treatment seemed to decrease in wet stability to a greater extent than any of the other treatments in falling by 40 percent to values ranging from 0.23 to 0.51 g/g. These gently-separated stabilities after compression were equal to all nondisturbed treatments except the noncultivated, nondisturbed. This shows the large effects of manipulating moist soils and breaking the insoluble bonds between aggregates. The cultivated surface soils and all of the subsoils seem to have fallen off equally due to their smaller volume of insoluble bonds when compared to the smaller decrease and larger volume of bonds in the noncultivated surface soil. The gently-separated treatment, wet-aggregate stabilities after compression were even lower than the crush/sieve-treatments' stabilities showing that more insoluble bonds were broken in the former soil than in the latter. The sonicated treatments still had the lowest wet-aggregate stabilities before and after compression but the gently-separated treatment had the next poorest wet-aggregate structure after compression. More inter- and intra-aggregate bonds have been broken in the gently-separated treatment than in any of the other treatments but the sonicated soil.

TABLE 6
WET-AGGREGATE STABILITIES

			Compressed (25 kg/cm^2)	
			Soil-Water Pressure	
Treatments	Initial Sample	Non-compressed	-300 mb	-1000 mb
	g/g			
Cultivated		Surface Soils		
Nondisturbed	0.48 (a)‡	0.48	0.30	0.28
Gently-separated	0.56 ± 0.01(a)	0.73	0.28	0.23
Crush/sieve	0.76 ± 0.11(b)	0.66	0.34	0.29
Sonicated	0.05 ± 0.01(c)	0.15	0.15	0.13
Noncultivated				
Nondisturbed	0.85 (a)	0.85	0.81	0.75
Gently-separated	0.86 ± 0.05(a)	0.97	0.50	0.51
Crush/sieve	0.95 ± 0.01(b)	0.94	0.67	0.61
Sonicated	0.18 ± 0.02(c)	0.15	0.30	0.32
Cultivated		Subsoils		
Nondisturbed	0.78 (a)	0.78	0.20	0.38
Gently-separated	0.69 ± 0.04(a)	0.66	0.25	0.25
Noncultivated				
Nondisturbed	0.74 (a)	0.74	0.35	0.62
Gently-separated	0.87 ± 0.01(b)	0.85	0.41	0.40

‡ Values followed by a common letter in each column are not significantly different at the 0.05 level.

Figures 6-8 contain graphs of the soil-water-characteristic curves of the various treatments. In every comparison of the nondisturbed and gently-separated treatments, the latter began with higher water contents and ended with lower water contents than did the former. This is an indication of a large volume of slightly larger pore spaces and looser structure which drains more readily at soil-water pressures between -10 mb and -200 mb than the nondisturbed soil. When compared with the crush/sieve and sonicated, surface-soil treatments, the gently-separated-treatment curves had steeper slopes in the -10 to -200 mb range and less water at -100 mb than any of the other treatments. In Fig. 6, the disturbed treatments all began and ended with approximately the same water contents but the gently-separated treatment lost its water early, mainly at soil-water pressures between -10 mb and -150 mb. In Fig. 7, the crush/sieve and gently-separated treatments lost the water from their pores at about the same rates and pore sizes and the nondisturbed and sonicated treatments reacted similarly to each other in the -10 mb to -100 mb range. All of the disturbed treatments started and ended at about the same water content. In Fig. 8, the gently-separated treatments started at higher water contents and lost their water sooner at small pressures but all of the treatments were mainly the same, especially after -200 mb pressure. The subsoils reacted more like the disturbed treatments and reflected as the disturbed do, a larger volume of more easily drained pores between aggregates because of the lack of bonds between these aggregates. Only the disturbed subsoils accurately represented the nondisturbed in characteristic-curve results. The gently-separated surface-soil treatments had been influenced the most as their contents were made up of individual aggregates with many low pressure, drainable pores. It

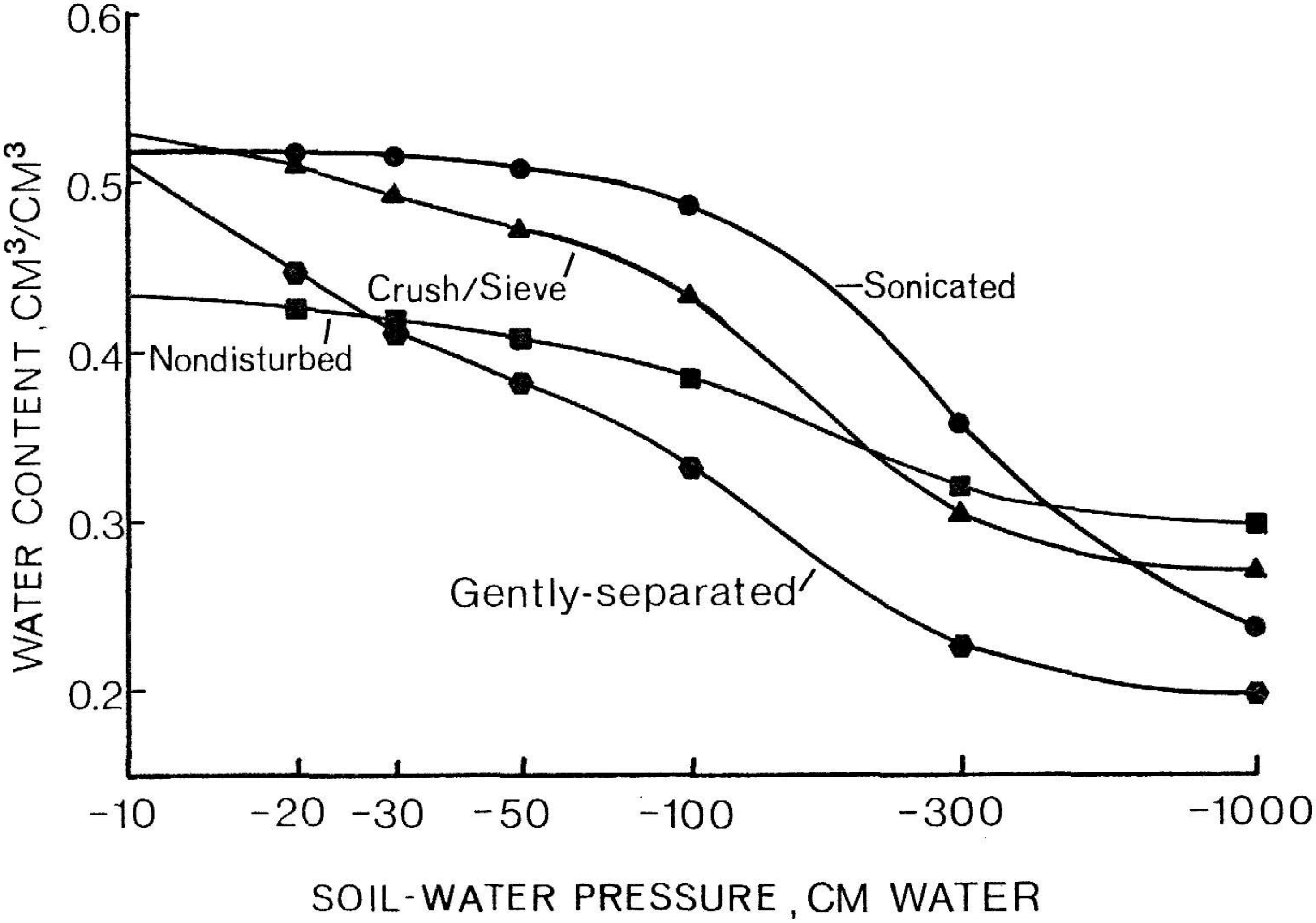

Fig. 6 Soil-water characteristic of cultivated Reading silt loam surface soil for indicated treatments.

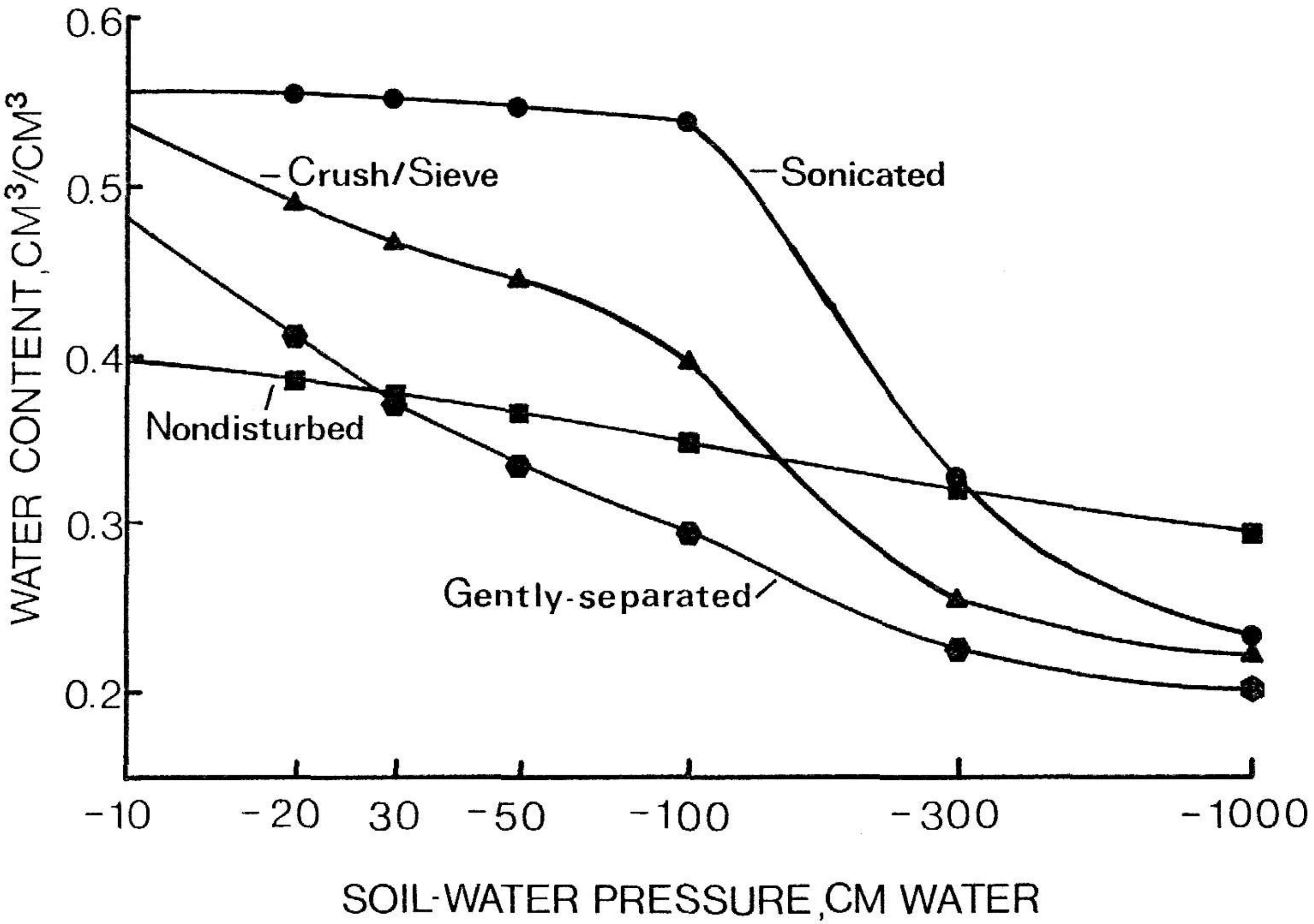

Fig. 7 Soil-water characteristic of noncultivated Reading silt loam surface soil for indicated treatments.

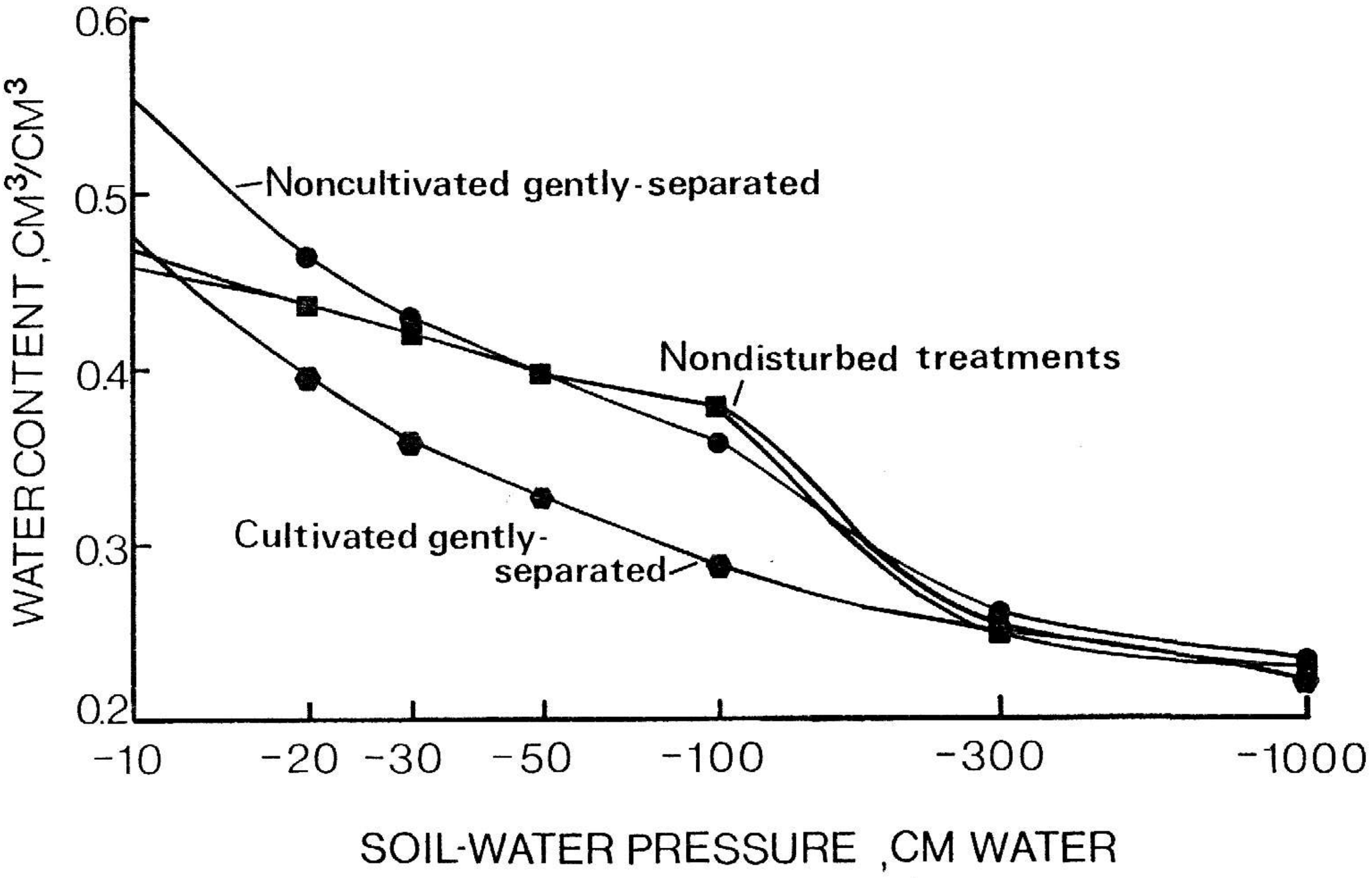

Fig. 8 Soil-water characteristic of cultivated and noncultivated Reading silt loam subsoils for indicated treatments.

isn't until the soil-water pressures greater than -400 mb, where the differences within aggregates are concerned that the disturbed, surface-soil treatments start to resemble the nondisturbed.

Due to lower bulk-density values and larger spaces between aggregates and particles, the gently-separated treatments had equal or higher saturated-hydraulic conductivities than did the nondisturbed treatments (Table 7). The conductivity of the gently-separated, cultivated surface soil value showed this the best as it was significantly higher (2.73 vs. 0.01) than its nondisturbed counterpart. In all of the other cases, the differences between these two weren't significant, but the gently-separated-treatment conductivities were almost always larger. The gently-separated treatment was about equal in conductivity to the crush/sieve treatment because the inter-aggregate bonds of both treatments had been broken allowing freer water flow. The sonicated surface soils had the lowest conductivities (0.13 to 0.23 cm/s x 1000). There were no major differences statistically between the subsoil treatments but the gently-separated treatment was equal to or larger than the nondisturbed.

In all of the bulk-density comparisons between the nondisturbed and gently-separated treatments, there was no significant difference after compression but there was before (Table 8). These results are similar to those found in Part I for the other disturbed treatments. Initially, the bulk densities of the gently-separated-soil treatments (Table 7) were much less (0.15 to 0.36 less) than that of the nondisturbed. This was due to the loose packing procedure and lack of aggregate bonds in the disturbed soils as compared to the firm-packed-soil cores and bonded aggregates of the nondisturbed. But in almost all cases, the bulk densities of the gently-separated cylinders went from the lowest before

TABLE 7
SATURATED-HYDRAULIC CONDUCTIVITIES

Treatments	Falling-Head Conductivity	Initial Bulk Density
	cm/s x 1000	g/cm^3
	Surface Soils	
Cultivated		
Nondisturbed	0.01 ± 0.001(a)‡	1.42 ± 0.03(a)
Gently-separated	2.73 ± 0.16(b)	1.07 ± 0.02(b)
Crush/sieve	1.98 ± 0.13(c)	1.22 ± 0.01(c)
Sonicated	0.13 ± 0.01(a)	1.12 ± 0.01(b)
Noncultivated		
Nondisturbed	3.67 ± 0.50(a)	1.12 ± 0.03(a)
Gently-separated	6.17 ± 0.41(a)	0.95 ± 0.02(b)
Crush/sieve	6.25 ± 2.04(a)	1.01 ± 0.02(c)
Sonicated	0.23 ± 0.12(b)	1.05 ± 0.01(c)
	Subsoils	
Cultivated		
Nondisturbed	4.39 ± 0.07(a)	1.32 ± 0.03(a)
Gently-separated	3.71 ± 2.25(a)	1.04 ± 0.01(b)
Noncultivated		
Nondisturbed	2.32 ± 1.46(a)	1.24 ± 0.05(a)
Gently-separated	6.02 ± 0.59(a)	1.09 ± 0.004(b)

‡ Values followed by a common letter in each column are not significantly different at the 0.05 level.

TABLE 8
COMPRESSION INDICES, C, AND FINAL BULK DENSITIES FROM INCREMENT LOADING TO 25 kg/cm^2

Treatments	Initial Soil-Water Pressure -300 mb		-1000 mb	
	C	g/cm^3	C	g/cm^3
		Surface Soils		
Cultivated				
Nondisturbed	0.31	1.76 ± 0.02(ab)‡	0.28	1.73 ± 0.06(a)
Gently-separated	0.37	1.69 ± 0.04(b)	0.43	1.78 ± 0.02(a)
Crush/sieve	0.33	1.81 ± 0.02(a)	0.35	1.88 ± 0.02(a)
Sonicated	0.37	1.86 ± 0.05(a)	0.35	1.76 ± 0.04(a)
Noncultivated				
Nondisturbed	0.29	1.61 ± 0.01(a)	0.22	1.62 ± 0.03(a)
Gently-separated	0.39	1.62 ± 0.03(a)	0.44	1.66 ± 0.01(a)
Crush/sieve	0.36	1.68 ± 0.02(a)	0.33	1.57 ± 0.02(a)
Sonicated	0.39	1.66 ± 0.01(a)	0.38	1.85 ± 0.13(b)
		Subsoils		
Cultivated				
Nondisturbed	0.27	1.78 ± 0.01(a)	0.33	1.71 ± 0.0 (a)
Gently-separated	0.44	1.81 ± 0.02(a)	0.39	1.76 ± 0.05(a)
Noncultivated				
Nondisturbed	0.29	1.69 ± 0.08(a)	0.33	1.69 ± 0.05(a)
Gently-separated	0.43	1.68 ± 0.06(a)	0.45	1.69 ± 0.02(a)

‡ Values followed by a common letter in each column are not significantly different at the 0.05 level.

compression to the highest after compression. These higher bulk densities weren't significantly different than the nondisturbed or other disturbed treatment due to the number of replications involved. The gently-separated-soil treatments, both surface soils and subsoils, reacted similarly and in the same manner to compression as the sonicated and crush/sieve-soil-treatments had.

Table 8 gives the values for the slopes of the compression curves of each soil with the larger values representing the more compressible soils. In all cases, the gently-separated treatments had much higher indices (0.03 to 0.22 higher) and were more compressible than the nondisturbed. This information and the bulk-density information show how much more compressible these gently-separated-soil treatments were. Part of that compressibility is due to the loosely packed, lower bulk density nature of the gently-separated treatments and their lack of inter-aggregate bonding. The gently-separated values for surface soils were also equal to or higher than the other disturbed treatments, the sonicated and crush/sieve. This might also be because of the lower gently-separated-treatment bulk densities and the greater destructive effect on the inter- and intra-aggregate bonds of the gently-separated cylinders as compared to the crush/sieve-soil treatments.

The penetration resistances (Table 9) of all of the disturbed treatments except the cultivated surface soils were much lower (4 to 14 kg/cm^2 lower) than their nondisturbed counterparts. These significantly smaller resistances for the disturbed soils (gently-separated, crush/sieve, and sonicated) were in large measure due to the individual particle and aggregate structure that lacked insoluble bonding between aggregates (Fig. 3-5). When a penetrometer was used on these disturbed soils at the indicated soil-water pressures, it acted similarly to a

TABLE 9
PENETRATION RESISTANCES

Treatments	Initial Soil-Water Pressure -300 mb	 -1000 mb
	---------- kg/cm^2 ----------	
	Surface Soils	
Cultivated		
Nondisturbed	4.19 ± 1.99(a)‡	7.56 ± 4.62(a)
Gently-separated	3.71 ± 0.32(a)	2.37 ± 0.48(b)
Crush/sieve	6.78 ± 0.63(b)	6.21 ± 1.39(ac)
Sonicated	2.77 ± 0.17(c)	4.08 ± 0.32(bc)
Noncultivated		
Nondisturbed	13.83 ± 0.95(a)	16.28 ± 4.19(a)
Gently-separated	2.85 ± 0.69(b)	2.22 ± 0.35(b)
Crush/sieve	4.81 ± 0.47(c)	4.87 ± 0.62(c)
Sonicated	2.64 ± 0.14(b)	3.20 ± 0.17(bc)
	Subsoils	
Cultivated		
Nondisturbed	7.56 ± 1.28(a)	11.48 ± 1.85(a)
Gently-separated	3.41 ± 0.20(b)	3.29 ± 0.53(b)
Noncultivated		
Nondisturbed	9.46 ± 3.03(a)	9.75 ± 3.13(a)
Gently-separated	3.57 ± 0.23(b)	4.67 ± 0.41(b)

‡ Values followed by a common letter in each column are not significantly different at the 0.05 level.

small compression head. The lack of interconnecting bonds and structure between aggregates left only the breaking of individual particles and aggregates to resist penetration. Due to the large variability and the similar effects of cultivation on these interconnecting bonds, the nondisturbed, cultivated surface soils gave only small indications of more complete structures (Table 9).

SUMMARY AND CONCLUSIONS

PART I

In analyzing the effects of simulated tillage on soil structure, we found that disturbing or manipulating the soils (crush/sieve and sonicated treatments) significantly degraded their structural stability but in varying degrees. These treatments emphasized this conclusion in their soil-moisture-characteristic-curve, dry-aggregate-stability, penetration-resistance, bulk-density, and compression-index results when compared with the nondisturbed-treatment results. The greater the amount of disturbance to the soil (sonication), the more the soil structural stability was degraded. This was seen in all of the tests. Especially with the moisture-characteristic curves, saturated-hydraulic conductivities, compression indices, and penetration resistances, disturbing the soils had less effect upon the cultivated soils than upon the noncultivated soils. This was probably due to the degrading effects that cultivation of the cultivated surface soil had already produced whereas the noncultivated had been untouched, had the best structure to degrade, and had the most insoluble inter-aggregate bonds to break. Compression of the soils during testing also had its largest effect upon the disturbed soils (Table 4). In short, disturbing soils for whatever purpose disrupts the soil structure in varying degrees depending upon the amount and kind of disturbance. Determining how much disruption should be allowed in soil testing so as to still retain beneficial and reliable information would be the next important item to decide upon.

As far as how well these disturbed soils represent the nondisturbed soils in structural stablity, two conclusions can be made. First and overall, the soil structures of the disturbed treatments were significantly different from and less stable than the soil structures of the nondisturbed treatments. This was shown in all of the test results. In most all cases, the sonicated treatments were more unlike the nondisturbed treatments than were the crush/sieve and the noncultivated, disturbed treatments were more unlike their nondisturbed controls than any of the other disturbed comparisons. Secondly, the disturbed treatments of the cultivated soil, and in particular the crush/sieve treatments, were most like their nondisturbed comparisons. So, in some cases, the crush/sieve practice on cultivated soils especially for wet-aggregate-stability, penetration-resistance, and compression testing might be a reliable measure of soil structural differences.

Finally, the most reliable and most beneficial tests of structural differences in soils, whether in soils that are manipulated or not, were the wet- and dry-aggregate stabilities; the moisture-characteristic curves; the bulk densities; the compression indices; and in most cases, the saturated-hydraulic conductivities. The most variable and unreliable test was the penetration resistance.

The S.E.M. photographs confirmed all of the indicated results of the other soil-structure measurements (Fig. 3-5). The nondisturbed soils had much larger amounts of insoluble (probably organic) bonds between the individual particles and aggregates producing a compound-unit, aggregate structure than did the disturbed soils (crush/sieve or sonicated). These bonds caused larger initial dry- and wet-aggregate stabilities (Tables 1-2) and caused these nondisturbed soils to be less compressible. When these bonds were broken during compression, the resultant soils of all treatments (except the noncultivated, nondisturbed surface soil which had the greatest amounts of these bonds) were very similar. All of the soils after the welding of particles during compression, increased their dry-aggregated stabilities but fell apart when wet-aggregate stabilities were run.

The soils with the most interconnecting bonds, the noncultivated and then cultivated, nondisturbed soils had the most stable structures followed by the crush/sieve and sonicated, and then compressed soils. The disturbed soils (crush/sieve) only represented the nondisturbed in their individual particle structures and not at all in their large compound-unit, inter-aggregate structures. Large structural differences were found among soils that were nondistured, or those that were crushed and sieved, or sonicated and then remolded.

PART II

In testing the gently-separated, surface-soil treatments, a common feature of a looser, more individual-aggregate structure was present which gave the soil higher hydraulic conductivities, lower bulk densities, better water-characteristic curves, larger values of J/m^2, and easier penetrabilities than the other surface soil treatments. This structure also caused these soils to be more compressible (Table 8) than the other treatments and in other ways have weaker inter-aggregate structures. Part of the larger compressibility and lower wet-aggregate stability after compression of the gently-separated surface soils, was probably due to the manipulation of these soils and the breaking of their inter-aggregate bonds while they were moist as happens to most soils that are cultivated when wet. In most cases, the gently-separated surface soils differed too much from the nondisturbed surface soils to be considered equal, but they represented the field condition of the Reading silt loam better than the other disturbed treatments. This was probably due to the gently-separated treatments' having been broken between aggregates whereas the crush/sieve and sonicated treatments were broken between and within aggregates. The sonicated, because it was completely dispersed into sand, silt, and clay particles and then remolded had the worst structure consisting of individual particles and a few aggregate structures. The crush/sieve surface soils had their compound- and individual-aggregate structures crushed or broken unnaturally leaving a partial aggregate structure whereas the gently-separated soils were broken naturally along planes of weakness. In all of these disturbed cases, the large compound-unit structure was destroyed and the soil in the cylinders consisted of individual particles and/or aggregates with few interconnecting bonds. This is the main reason why whenever a soil is brought in from the field in its disturbed or nondisturbed state, crushed or broken apart, and then remolded into cylinders, the compound-unit structure can't possibly resemble that of the nondisturbed soil. It could very well still have the same individual-particle and individual-aggregate structure and stability but most of the tests measured the compound-unit and not the individual-aggregate structures. Since the wet-aggregate-stability test was considered as a good measure of individual-aggregate structure, there had even been a change in the individual-aggregate structures through disturbing the soils for experimental use.

The gently-separated-treatment subsoils seem to be less affected by the disturbances on an individual-aggregate basis than the gently-separated-treatment surface soils were. They still reflected the same loose-bonded structure that the gently-separated surface soils did, but they overall compared favorably with the nondisturbed subsoils.

I feel more could be done in developing tests to look at the individual aggregate changes and to compare the compound-unit structural changes after the disturbed soils have been compressed or remolded to the same bulk densities as the nondisturbed soils and after organic materials have been used in attempting to remold the soils and rebuild the inter-aggregate bonds.

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CHAPTER II

READING SILT LOAM STRUCTURAL CHANGES WITH CULTIVATION

ABSTRACT

Conventional tillage has been shown to have degrading effects upon soil structure with time. Experiments are usually limited to a few different kinds and usually just the surface soil is tested. In preparation for another soil-structure-research project, 10 experiments were run on nondisturbed surface soil and subsoil samples of the cultivated and noncultivated Reading silt loam (a fine, mixed, mesic, Typic Argiudoll) to compare their structure differences and to use them to better understand simulated-tillage effects. This project outlines the comparisons of the effects of cultivation on soils of similar composition but either in a noncultivated or cultivated state. Nondisturbed soil cores of the A1 and B1 horizons were taken using a double cylinder, hammer-driven core sampler and the soil strucural differences were measured by soil-water-characteristic curves; saturated-hydraulic conductivities; penetration resistances; compression indices; bulk densities; wet-aggregate stabilities; dry-aggregate stabilities using a rotary sieve and on an energy basis; particle-size analyses; and soil fertilities. The results showed that the noncultivated surface soil was significantly more stable structurally than the cultivated surface soil, that both subsoils were virtually the same structurally, and that the cultivated surface soil was taking on similar characteristics to the cultivated subsoil.

INTRODUCTION

Conventional tillage has been shown in many individual tests on soils to have a degrading effect with time. Chepil (4), Skidmore (20), Garkusha (6), Gromyko (9, 10), Tallarico (22), Tomka (23), Karnaukhov (11), Williams (27), Wiklert (25), Birke (1), Skankarnarayana (19), Tyulina (24), Dvoracsek (5) and Olmstead (15), all reported that the wet-aggregate stabilities of noncultivated surface soils decreased by 20 to 80 percent after cultivation and that the insoluble bonding cements had been broken. Chepil (4), Tallarico (22), Gromyko (8), Skankarnarayana (19), and Dvoracsek (5) all found that the proportion of large aggregates decreased with cultivation. Both of these results could be tied to the fact that organic matter and Nitrogen contents decreased up to 75 percent in cultivated surface soils as discovered by Bouma (3), Spencer (21), Gromyko (9, 10), Williams (26), Grinchenko (7), Schmidt (18), Tallarico (22), Karnaukhov (11), and Tyulina (24). Bouma (3), Skidmore (20), and Spencer (21) found increased clays and sands and more basic soil cations in the cultivated surface soils and more Ca and Mg in the cultivated subsoils. Olmstead (15) and Skankarnarayana (19) reported only small structural changes in the subsoils of cultivated soils.

In many research projects, only a few tests have been used to determine the effects of cultivation on a soil that had been noncultivated. Birke (1) used porosities and bulk densities; Spencer (21), Garkusha (6), Williams (26), Grinchenko (7), and Schmidt (18) used fertilities; Chepil (4), Williams (27), and Tomka (23) used aggregate stabilities; Karnaukhov (11), Gromyko (9, 10), Tallarico (22), Tyulina (24), Skankarnarayana (19) used wet-aggregate stabilities and fertilities; and Wiklert (25), Bouma (3), Dvoracsek (5), Olmstead (15), Gromyko (8), and Skidmore (20) used a combination of three to four experiments including porosities; hydraulic conductivities; densities; fertilities; and aggregate distributions and stabilities to determine the effects of cultivation. In many research projects of this type, only the Ap horizon has been considered. In the list of papers just mentioned, only eight considered the changes in subsoils due to cultivation. In some of those eight, the changes in the soil profiles were examined to a much greater depth but usually only considered fertility changes.

In light of these findings, the purpose of this research was to determine through 9 different testing procedures, the structural changes (not just the aggregation and fertility changes) that occur when a soil, particularly the Reading silt loam has been intensively cultivated. It reports the effects of real cultivation in order to increase our understanding of the effects of simulated tillage.

MATERIALS AND METHODS

Nondisturbed samples of the Reading silt loam (a fine, mixed, mesic, Typic Argiudoll) were obtained from a noncultivated prairie and an adjacent cultivated field at the Konza Prairie Research Natural area. The samples were taken from the surface soils (1- to 7-cm depth) and from the subsoils (46-cm to 52-cm depth) of the two locations in July of 1979 and 1980. The soil-core samples (8.6 x 6 cm-8 replications) were taken using a double cylinder, hammer-driven, soil-core sampler (2, 17).

The physical and structural differences of all of the soils were measured by the following methods as outlined in Powers and Skidmore (16): bulk densities; wet- and dry-aggregate stabilities; saturated-hydraulic conductivities; compression indices and penetration resistances at soil-water pressures of -300 mb and -1000 mb and soil-water-characteristic curves (-10 to -1000 mb). Dry-aggregate stabilities using a rotary sieve, soil fertilities, and particle-size analyses were also determined.

The bulk densities were determined by weights of the dry soil for each soil-core volume. The wet-aggregate stabilities were done by a flash method outlined by Kemper (12) and the dry-aggregate stabilities were done on an energy basis where the energy to produce new surface area (J/m^2) was measured in crushing clods (Skidmore and Powers, Agronomy Abstracts, p. 192, 1980). Saturated-hydraulic conductivities were done on a falling-head basis as outlined by Klute (13). The Instron universal-testing instrument was used to apply successive increments of stress in compression-index calculation and to insert probes into the soil for determining penetration resistances after the soils were brought to equilibrium at soil-water pressures of -300 and -1000 mb (14, 16). Soil-water characteristics were determined by use of hanging-water columns and tempe pressure cells.

Particle-size analyses were determined as follows: ultrasonically dispersed, wet sieved for sands, centrifuged for silt and clay separation, and calculated for percentages. 10 gm of soil in a 250-ml metal beaker at a 1:10 soil/water ratio were sonicated and magnetically stirred for the 10-minute dispersion. The silts and clays were washed through a 0.05-mm sieve into a 3000-ml beaker and the sands on the sieve were dried. The silt/clay suspension was centrifuged for 5-6 minutes depending on the water temperature to separate the silts and clays in the 500-ml centrifuge bottles. The clay suspension was then suctioned out of the bottles with a vacuum pump, distilled water added, and the centrifuging repeated (8-10 times) until the suspension was clear. The separated silts and clays were then dried. The dry sands were sieved again on a 0.05-mm sieve to complete the sand/silt separation and the three size fractions (sand, silt, and clay) were weighed. The weight of each size fraction was divided by 10 gm and multiplied by 100 to get percentages.

Analysis of variance and least significant differences at the 0.05 and 0.01 levels were used to analyze the results of the various treatments.

RESULTS AND DISCUSSION

The Reading silt loam from a cultivated field is described in the Riley County, Kansas Soil Survey Manual as follows:

A1- 0 to 28 cm, dark grayish-brown (10YR 3/2) silt loam when moist; moderate fine, granular structure; medium acid.

B1- 28 to 51 cm, dark grayish-brown (10YR 3/2) light silty clay loam when moist; moderate, fine, granular structure; medium acid.

B2t- 51 to 102 cm

Our soil samples taken from a cultivated field 442 m north and 381 m east of the southwest corner of sec. 12, T. 11 S., R. 7 E., and from a noncultivated-prairie, creek bank 366 m north and 335 m east of the southwest corner of sec. 12, T. 11 S., R. 7 E., were similar to Soil Survey descriptions and similar to each other as follows:

Cultivated

A1- 0 to 36 cm, dark grayish-brown (10YR 3/2) silty clay loam when moist; weak, fine, granular structure; 0.5- to 1.0-mm aggregates.

B1- 36 to 53 cm, dark grayish-brown (10YR 3/2) silty clay loam when moist; moderate, fine, subangular blocky structure; 2- to 4-mm aggregates.

B2t- 53 to 102 cm

Noncultivated

A1- 0 to 36 cm, dark grayish-brown (10YR 3/2) silt loam when moist; moderate to strong, fine, granular structure; 0.5- to 3-mm aggregates.

B1- 36 to 53 cm, dark grayish-brown (7.5YR 3/2) silty clay loam when moist; moderate, fine subangular blocky structure; 1- to 3-mm aggregates.

B2t- 53 to 102 cm.

Other general characteristics of the cultivated and noncultivated

Reading silt loam soil are shown in Tables 10-11. The noncultivated surface soil had the only difference in pH and was more acidic at 6.4 than the rest of the treatments at 6.7. Leaching and oxidation of acidic organic matter and fertilizer-supplied basic cations has changed the cultivated surface soil from its original status. The 2244 kg/ha of effective calcium carbonate in the noncultivated surface soil shows the large amounts of organic matter present for adsorbing calcium. The differences due to organic matter are also present in the large total N values of the noncultivated surface soil (2100) compared to the large amounts of N that have been leached into the cultivated subsoil (1150) but not the noncultivated subsoil (850). All of these would produce a stronger bonded noncultivated surface soil. The basic cations (Ca, Mg, P, K) were all more abundant in the cultivated surface soils and noncultivated subsoils than in the noncultivated surface soils and cultivated subsoils except for the Ca content in the noncultivated subsoil. These larger values of basic cations in the cultivated surface soil could be due to fertilizer applications in the last eight years or due to the lower amounts of organic matter tying up the cations of the cultivated soil. Another reason is the higher clay content (10 Percent higher) in cultivated surface soil adsorbing the cations. All of the soils were naturally fertile but cultivation is beginning to make an effect.

In Table 11, the particle-size analyses of the soils show that the cultivated soils have higher clay contents than do the noncultivated soils (surface soils, 28.3 to 16.9, subsoils, 30 to 27.8). The cultivated, surface-soil clay content might be due to erosion of the surface soil and stirring of the subsoil to the surface during

TABLE 10
READING SILT LOAM SOIL FERTILITY

Nondisturbed Treatments	pH	Effective Calcium Carbonate	Avail. P	Exch. K	Ca	Mg	Total N
		----------------- kg/ha. -----------------					ppm
Surface Soils							
Cultivated	6.7	----	10.1	423	5875	687	1490
Noncultivated	6.4	2244	3.4	335	2883	433	2100
Subsoils							
Cultivated	6.7	----	2.2	257	4491	432	1150
Noncultivated	6.7	----	5.6	463	4317	968	850

TABLE 11
PARTICLE-SIZE ANALYSIS AND DRY-AGGREGATE STABILITY

Nondisturbed Treatments	Sand	Silt	Clay	July '79	Mar '80	July '80
	----------------	----------------	----------------	Percentages, %	----------------	----------------
Surface Soils						
Cultivated	11.1	60.6	28.3	94.0 ± 4.0	93.0 ± 4.0	99.0 ± 4.0
Noncultivated	6.2	76.9	16.9	97.0 ± 2.0		97.0 ± 7.0
Subsoils						
Cultivated	3.9	66.1	30.0			
Noncultivated	12.0	60.2	27.8			

cultivation. The particle-size changes also show in the noncultivated surface soil having more (76.9 to 60.6 more) silt than the cultivated due to the erosion of the silt after cultivation. The subsoil values for the most part are the same.

Table 11 also gives values for dry-aggregate stabilities when a rotary sieve is used. Due to a large amount of roots in the noncultivated surface soil, the stabilities are more difficult to accurately obtain. In July of 1979, with the cultivated surface soil under wheat, the noncultivated soil had a slightly higher dry stability but in July of 1980, with the cultivated soil under soybeans, the cultivated seemed to be more stable. Seasonal variations affected the dry stability as shown by the lower March, 1980 stability due to freezing and thawing. Both soils showed good overall stability and structure.

Energy-based dry-aggregate stabilities (Table 12) were significantly different in almost all comparisons of the cultivated and noncultivated soils. In almost all cases, the noncultivated soils, both surface soils and subsoils, were much more stable (5.00 to 16.00 J/m^2 more stable) than the cultivated soils both before and after compression. The noncompressed, noncultivated soils had much stronger stabilities. Compression increased all of the stability values for all soil treatments and caused the differences between the noncultivated and cultivated soils to decrease. The subsoils were also more stable than the surface soils were probably due to their larger clay contents.

The wet-aggregate-stability value for the noncultivated surface soil was much higher initially (37 percent higher) than that of the cultivated surface soil and it remained high even after compression

TABLE 12

DRY-AGGREGATE STABILITY (ENERGY BASED)

Nondisturbed Treatments	Noncompressed	Compressed (25 kg/cm^2) Soil-Water Pressure -300 mb	Compressed (25 kg/cm^2) Soil-Water Pressure -1000 mb
	J/m^2	J/m^2	J/m^2
Surface Soils			
Cultivated	7.18 ± 3.10	33.54 ± 7.97	30.46 ± 9.94
Noncultivated	12.52 ± 2.82**	40.25 ± 5.99*	38.97 ± 5.40*
Subsoils			
Cultivated	20.97 ± 3.04	48.03 ± 5.57	40.76 ± 8.12
Noncultivated	36.72 ± 0.22**	55.33 ± 14.10	55.35 ± 21.63*

* and ** Significance at the 0.05 and 0.01 levels of confidence, respectively.

TABLE 13
WET-AGGREGATE STABILITIES

Nondisturbed Treatments	Initial Noncompressed Sample	Compressed (25 kg/cm^2) Soil-Water Pressure -300 mb	-1000 mb
	------------- g/g	-------------	
Surface Soils			
Cultivated	0.48	0.30	0.28
Noncultivated	0.85	0.81	0.75
Subsoils			
Cultivated	0.78	0.20	0.38
Noncultivated	0.74	0.35	0.62

(Table 13). The larger amounts of organic matter and better insoluble, inter-aggregate bonding helped to keep this soil stable even after compression. The noncultivated and cultivated subsoils were about the same initially with very high stabilities (74-78 percent). The cultivated surface soil wasn't very stable initially and was even less stable after compression, decreasing in stability by 40 percent.

The soil-water-characteristic curves (Fig. 9) for the subsoils are virtually the same and the cultivated surface soil from -10 mb to -100 mb is similar to the subsoils. This indicates that the cultivated surface soil could have had subsoil incorporated into it or is becoming similar to a subsoil in its properties. The noncultivated surface soil is quite different at soil-water pressures between -10 and -200 mb than the other treatments and exhibits the best structure of all.

The noncultivated surface soil was able to conduct a much higher rate of water through the soil than the cultivated surface soil (Table 14). Although there was no major difference between the saturated-hydraulic conductivities of the subsoils, the cultivated subsoil still had a much larger conductivity. This was probably due to the great variability in the noncultivated subsoil tests.

In all of the surface soil comparisons of bulk densities (Table 15), the cultivated surface soils had the larger, more dense values (0.11 to 0.30 denser) and in two out of three cases, the difference was significant. The cultivated, surface-soil densities compared well with all of the subsoil densities and all three treatments were more compressible than the noncultivated surface soil (Table 15) due to higher amounts of clay and fewer insoluble, inter-aggregate bonds. Organic matter also helped the noncultivated surface soil to have a

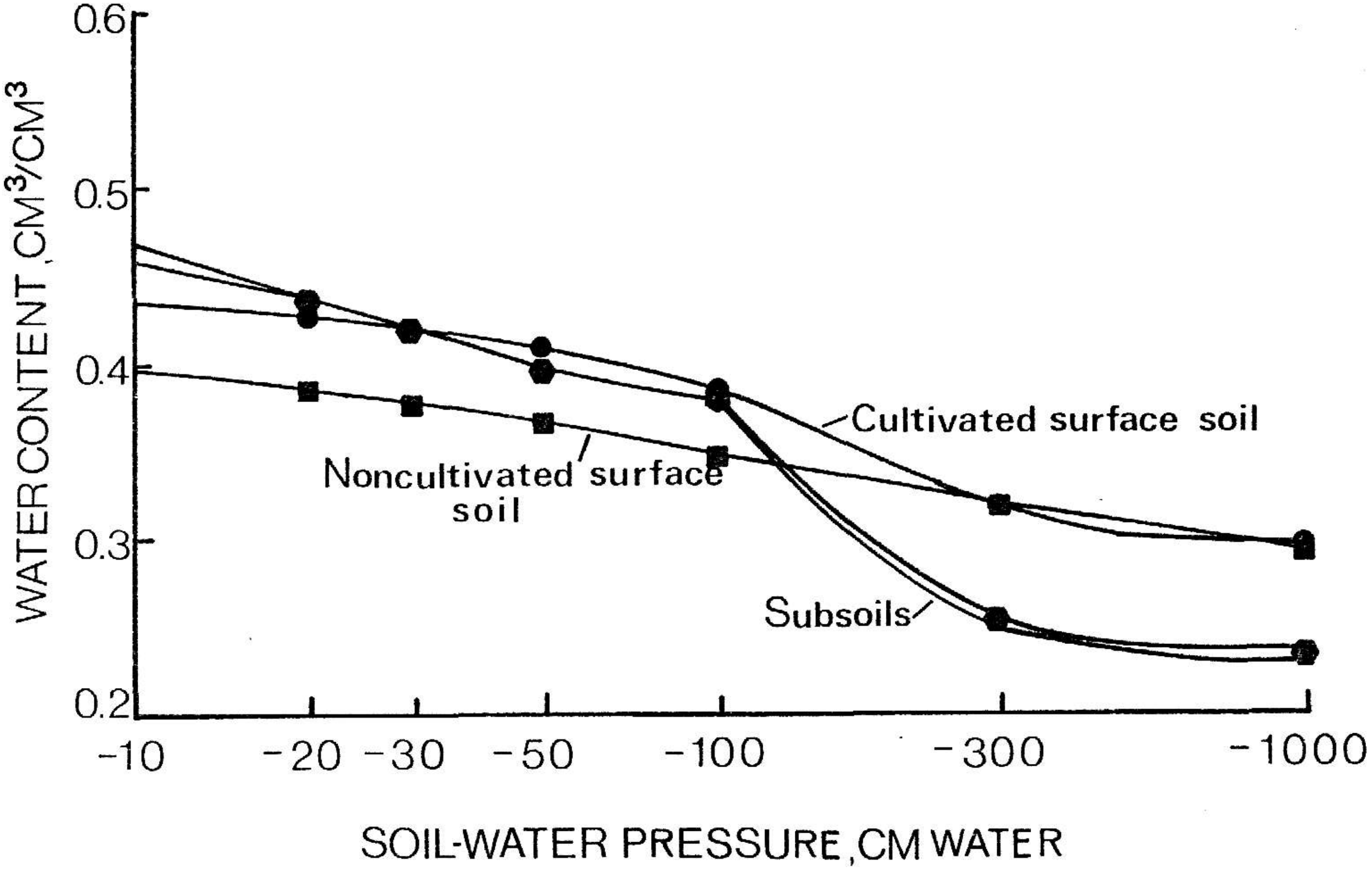

Fig. 9 Soil-water characteristic of the cultivated and noncultivated Reading silt loam surface soils and subsoils (nondisturbed treatments).

TABLE 14
SATURATED-HYDRAULIC CONDUCTIVITIES

Nondisturbed Treatments	Falling-Head Conductivity	Initial Bulk Density
	cm/s x 1000	g/cm^3
Surface Soils		
Cultivated	0.01 ± 0.001	1.47 ± 0.03**
Noncultivated	3.67 ± 0.50**	1.16 ± 0.03
Subsoils		
Cultivated	4.39 ± 0.07	1.36 ± 0.03
Noncultivated	2.32 ± 1.46	1.28 ± 0.05

** Significance at the 0.01 level of confidence

TABLE 15
COMPRESSION INDICES, C, AND FINAL BULK DENSITIES FROM INCREMENT LOADING TO 25 kg/cm^2

Nondisturbed Treatments	Initial Soil-Water Pressure			
	-300 mb		-1000 mb	
	C	g/cm^3	C	g/cm^3
Surface Soils				
Cultivated	0.31	1.76 ± 0.02**	0.28	1.73 ± 0.06
Noncultivated	0.29	1.61 ± 0.01	0.22	1.62 ± 0.03
Subsoils				
Cultivated	0.27	1.78 ± 0.01	0.33	1.71 ± 0.00
Noncultivated	0.29	1.69 ± 0.08	0.33	1.69 ± 0.05

** Significance at the 0.01 level of confidence

lower bulk density, a more complete, compound-unit structure, and a less compressible soil. The subsoil densities weren't significantly different but the cultivated densities were all from 0.02 to 0.09 g/cm^3 larger than the noncultivated.

The cultivated surface soils had steeper slopes and were more compressible than the noncultivated (Table 15) during compression at soil-water pressures of -300 mb and -1000 mb. This reflects greater clay content and fewer insoluble bonds between aggregates. The subsoil values are equal at -1000 mb compression and the noncultivated is more compressible at -300 mb compression.

There were major differences between the penetration resistances of the cultivated and noncultivated soils, only when the surface soils were compared (Table 16). In those surface-soil comparisons, the cultivated resistances were much less (about 9 kg/cm^2 less) than the noncultivated. These values were significantly different and reflected a weaker structure in the cultivated surface soils. There was no significant difference between the noncultivated and cultivated subsoils reflecting the fact that the cultivated subsoil hadn't been affected as much by cultivation as the cultivated surface soil (Table 16).

TABLE 16
PENETRATION RESISTANCES

Nondisturbed Treatments	Initial Soil-Water Pressure -300 mb	 -1000 mb
	------- kg/cm^2 -------	
Surface Soils		
Cultivated	4.19 ± 1.99	7.56 ± 4.62
Noncultivated	13.88 ± 0.95**	16.28 ± 4.19**
Subsoils		
Cultivated	7.65 ± 1.28	11.48 ± 1.85
Noncultivated	9.46 ± 3.03	9.75 ± 3.13

** Significance at the 0.01 level of confidence

SUMMARY AND CONCLUSIONS

The noncultivated surface soil was significantly more stable than the cultivated surface soil. This result was not surprising or new, but was confirmed. The noncultivated surface soils exhibited better structures as expressed by lower compressibilities, bulk densities, and water characteristics, and by higher wet- and dry-aggregate stabilities, saturated-hydraulic conductivities, and penetration resistances.

The cultivated and noncultivated subsoils were similar. This was especially true of values for saturated-hydraulic conductivities, water characteristics, wet-aggregate stabilities, bulk densities, and penetration resistances. The indication is that cultivation has affected the surface soils much more than the subsoils.

Finally, the cultivated surface soil had equal to or worse structure and stability than the subsoils. The cultivated surface soil and the subsoils were about equal in pH, bulk density after compression, clay content, water characteristic, penetration resistance, and wet-aggregate stability. In my estimation, the cultivated surface soil is being eroded or oxidized away and the stable insoluble, inter- and intra-aggregate bonds are being broken causing it to have weaker structural characteristics than the subsoils or noncultivated surface soil.

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SOIL STRUCTURE AS INFLUENCED BY SIMULATED TILLAGE

by

DAVID H. POWERS

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Soil is often intensively manipulated tillage, equipment traffic, and preparation for laboratory analysis. Realizing that manipulated and fabricated soils have been and are being used in soil-structure research, we used surface soil and subsoil samples of cultivated and noncultivated Reading silt loam (fine, mixed, mesic, Typic Argiudolls) to evaluate the effects of simulated tillage on soil structure and to determine how well the structures of disturbed soils represent the structures of nondisturbed soils of similar composition. Soil cores 8.6 by 6 cm were formed after the following treatments had been applied: ultrasonicaly dispersed and freeze dried; crushed and passed through a 2-mm sieve; gently separated along planes of weakness while moist; and nondisturbed. The soil-structure differences were evaluated by soil-water-characteristic curves, saturated-hydraulic conductivities, penetration resistances, compression indices, bulk densities, wet- and dry-aggregate stabilities, and scanning-electron-microscope photographs. The results show that the soil structures of fabricated, intensively or even mildly manipulated soils were significantly different from the nondisturbed soils of the same makeup. The greater the disturbance, the greater the differences between the nondisturbed and disturbed soils. The main differences were caused by the destruction of the cements and bonds between individual aggregates (mainly insoluble bonds) which create large, compound-unit (ped) structures. These compound-unit structures were also changed in the cultivated surface soil causing it to be less stable than the noncultivated. The subsoils were stable and unchanged.