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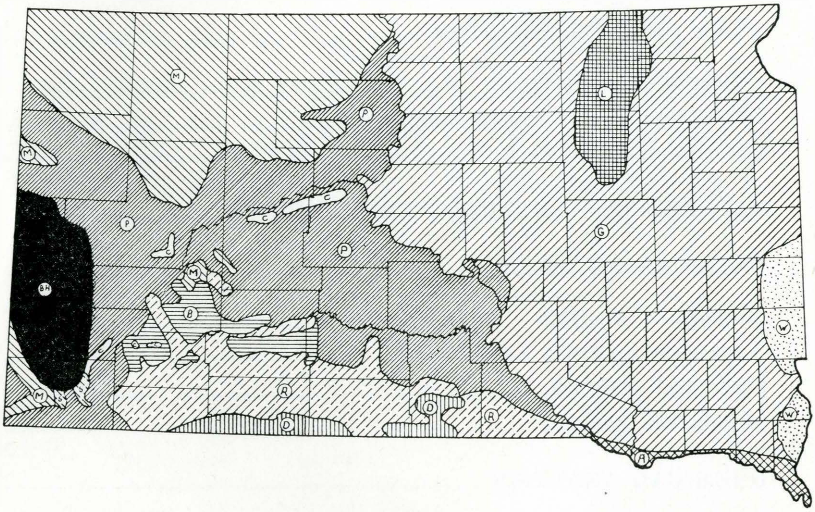
FIGURE 1

PRINCIPAL SOIL AREAS IN SOUTH DAKOTA[1]



Legend

A. Missouri Bottom Soils
B. Bad Land Soils
C. Cheyenne Loam Soils
D. Dune Sand
G. Glacial Soils
L. Lacustrine Soils
M. Morton Soils
P. Pierre Soils
R. Rosebud Soils
S. Smithwick Soils
W. Loessial Soils
B.H. Black Hills

[1]From Map by J. G. Hutton, South Dakota Bulletin No.—238

A Preliminary Study of the Effect of Cultivation on Certain Chemical and Physical Properties of Some South Dakota Soils

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Introduction.—Soil nutrient losses have followed closely in the paths of advancing frontiers in agriculture. Remedies for depletion as the result of overcropping were sought by George Washington, whose observation and interest in soil nutrient losses probably represent the earliest attention given to land exploitation in the United States, which at the present time has become a problem of national concern.

Soil losses have been attributed to a number of causes, among which are cropping, erosion, leaching, burning and rapid oxidation of organic matter in the soil. Associated with soil nutrient losses, certain significant physical and chemical changes may occur in the soil.

The soils of South Dakota lie entirely in the area commonly designated as the Pedocal group. The characteristic feature of the Pedocal group is a horizon of calcium carbonate accumulation in the soil profile which indicates that these soils have developed in an environment of limited rainfall.

It has been generally observed that in regions of limited rainfall the agricultural practices which have prevailed since virgin soils were cultivated, have resulted in the loss of considerable of the original organic matter and nitrogen. The cropping systems commonly practiced have not included the planting of a legume to restore the nitrogen and organic matter losses due to cultivation and much of the organic matter of the non-leguminous crop residues are partially lost by feeding to livestock, while some are totally lost by burning.

Associated with the loss of organic matter certain physical changes may occur in the soil which have a bearing upon soil structure. Diminution of organic matter of soils, and the probable subsequent change in soil structure, have been regarded as contributory factors in the severity of wind erosion, and to some extent water erosion in the Great Plains area.

The present study aims to make some contribution towards an understanding of the effect of one factor, namely, the cultivation of South Dakota soils, upon (1) the nutrient losses as determined by changes in chemical composition of the soil, and upon (2) the physical properties of the soil.

Review of Literature.—In the report of the eleventh annual meeting of the American Soil Survey Association (2) the observations of several field men on the cultural changes in soils are summarized. G. W. Conrey states that in certain soils (Superior clay in Wisconsin and Crosby silty clay in Ohio) cultivation has changed the texture of the soil to such an extent that a fence line may separate two soils so radically different that identification may be very confusing. J. O. Veatch of Michigan found mixing of the horizons and either gains or losses in the nitrogen, phosphorus, and lime content, depending upon a number of factors such as the type of soil and methods of farming. W. J. Geib states that in Wisconsin soils the most marked change due to cultivation is the loss in organic matter. A. H. Joel of Saskatchewan found a decrease in crude organic matter and a breakdown of structure resulting from cultivation, E. G. Fitzpatrick of Oklahoma observed that in mature soils cultivation has resulted in loss of nitrogen, no decrease in fertility, and the removal of the upper one-fourth to one-half inch of soil by erosion. In immature soils one to four inches of soil had been removed, and the fertility had been reduced five to ten per cent after ten years of cultivation.

Bradfield (8) states, "The best structure is usually found in virgin soils that have been in sod for several years."

A slight increase in the sand content of cultivated Southern High Plains soils over virgin soils of the same area, due to cropping and wind erosion, was reported by Daniel (10).

Daniel and Langham (11) found a decrease in organic matter and total nitrogen due to cultivation in Oklahoma Panhandle Soils.

DeTurk (13) found a migration of colloids from the surface soils downward as the result of cultivation of Illinois soils. He found also that crop rotations commonly practiced induce a shift in organic matter to lower levels than those in the virgin state. He states that, "Plant residues return phosphorus mainly to the surface soil, while root systems remove it from the surface and also from greater depths."

DeTurk, Bauer, and Smith (14) estimated that, based on crop yield, a loss of six pounds of phosphorus per year from Illinois soils, especially the top 6⅔ inches, occurred. They found no pronounced differences in the total amounts of calcium, magnesium, or sulfur due to cropping or cultivation, except for a gain in calcium in the surface soil of treated plots where calcium was added both as lime and as the phosphate.

With the exception of nitrogen, Dorman (14) reports that in Michigan soils a comparison of analyses of cropped and virgin soils showed no consistent differences. He found that in lighter textured soils phosphorus was decreased by cropping while in heavier soils it was increased. With reference to the effect of cultivation and cropping, no change in pH was found, and only small differences in exchangeable hydrogen were noted; both increases and decreases in base exchange capacity were found; with one exception, that readily available phosphorus was greater in the virgin soil; and in the cropped soils the greatest response to nitrate fertilizers resulted.

Millar (17) studied the rate of solution of virgin and cultivated soils, using the freezing point method, and found that virgin soils possess the power of giving up soluble material at a greater rate than the corresponding cropped soils. He also found that subsoils from depleted areas had as great a solubility as subsoils from the corresponding virgin soils, indicating that most crop plants feed primarily in the surface or plowed stratum of the soil.

Shedd (19), in Kentucky soils, found that in most cases a loss in calcium was found as the result of cultivation. Many soils were found to be so low in calcium that their deficiency in this constituent appeared to be as important as deficiencies in phosphorous and nitrogen.

Swanson (2) found in Kansas soils that from 22.6 per cent to 43.5 per cent of the nitrogen and from 23.3 per cent to 51.3 per cent of the organic matter, based on the virgin soil content, was lost through cultivation.

Swanson and Miller (21) in a study of Kansas soils, report losses in sulfur from the surface soils greater than the amount removed in crops, and concluded that sulfofication and leaching were the causes.

The findings of the majority of the soil investigators which are pertinent to the interests of the present study, seem to indicate a general loss of nitrogen, calcium and phosphorous in cultivated soils when compared with virgin soils. These investigators point to some changes in soil texture and structure caused by cultivation. Base exchange capacity and rate of solution of soil nutrients were found to be lower in cultivated soils. Reduced fertility and erosion were generally observed. Probably the most pronounced loss due to cultivation was the loss of organic matter.

Purpose of Investigation.—From the agricultural viewpoint any chemical and physical changes in the soil brought about by cultivation which have a bearing upon soil erosion and soil fertility are highly significant.

The general purpose of this investigation, therefore, was to determine the effect of cropping upon the physical and chemical properties of South Dakota soils.

In order to determine the nature and extent of the changes which have taken place in the soil, certain chemical and physical studies of the soils were undertaken. Samples of virgin soils and of cultivated soils were selected from the principal types in South Dakota. A comparison of the chemical and physical properties of virgin and of cultivated soils could thus be made in order to determine the possible physical and chemical changes resulting from cultivation.

The specific objects of this investigation may be summarized under the following heads:

I. Physical studies

1. The effect of cultivation upon the size and stability of the soil aggregates or granules.
2. The effect of cultivation upon the mechanical composition of the soil as determined by mechanical analysis.
3. The relationship of the organic matter content of the soil to the size and stability of soil aggregates.

II. Chemical studies

1. The determination of the loss of nitrogen and phosphorous from the soil due to cropping.
2. A study of the organic matter and organic matter-nitrogen ratios of virgin and cultivated soils.
3. A study of the base exchange properties of virgin and cultivated soils.
4. The determination of the soil reaction of virgin and cultivated soils as measured in terms of pH.

Plan of Investigation

Collection of Materials.—An attempt was made to obtain samples of the most important soils series in the state. The following series were selected: Barnes, Bearden, Moody, Williams, Orman, and Pierre.

The Barnes, Bearden and Moody series are found east of the Missouri River. They are dark colored soils belonging to the Chernozem group.

The Orman and Pierre soils are found west of the Missouri river in the region of the Chestnuterths.

The Williams series lie in the transition zone east of the Missouri river between the dark brown soils of the Chestnuterth group and the dark soils of the Chernozem group.

For the purpose of this study a virgin soil is considered any soil which has not been broken with a plow or otherwise cultivated; its vegetative covering may have been removed for hay or the land may have been pastured. Cultivated soil is any soil which has been plowed or other-

Table 1 gives a description of samples. Samples labeled with the same letter are pairs, the virgin soil of the pair being specified by "sub 1" and the cultivated soil of the pair by "sub 2."

TABLE 1.—DESCRIPTION AND LOCATION OF SOIL SAMPLES

Sample	Virgin or Cultivated	Type	Dominant Vegetation	Location
A_1	Virgin	Pierre Clay	**Buchloe dactyloides Bouteloua gracilis Opuntia fragilis**	Exp. Farm Cottonwood, S. Dak.
A_2	Cultivated	Pierre Clay	None	Same as A_1
B_1	Virgin	Orman Clay	**Buchloe dactyloides Bouteloua gracilis**	Exp. Farm Cottonwood, S. Dak.
B_2	Cultivated	Orman Clay	None	Same as B_1
C_1	Virgin	Williams Clay	**Bouteloua gracilis**	Cemetery S. E. of Highmore, S. Dak.
C_2	Cultivated	Williams Clay loam	None	Same as C_1
D_1	Virgin	Barnes Sandy loam	**Agropyron pauci-florum**	Virgin pasture N. W. of Huron, S. Dak.
D_2	Cultivated	Barnes Sandy loam	None	Same at D_1
E_1	Virgin	Bearden Silt loam	**A. pauciflorum**	Cemetery S. E. of Brookings, S. Dak.
E_2	Cultivated	Bearden Clay loam	None	Same as E_1
F_1	Virgin	Barnes Sandy loam	**A. pauciflorum**	Cemetery N. W. of Brookings, S. Dak.
F_2	Cultivated	Barnes Sandy loam	None	Same as F_1
G_1	Virgin	Moody Silty Clay	**A. pauciflorum**	Virgin pasture S. of Brookings, S. Dak.
G_2	Cultivated	Moody Silty Clay	None	Same as G_1
H_1	Virgin	Moody Clay loam	**A. pauciflorum**	Cemetery N. E. of Flandreau, S. Dak.
H_2	Cultivated	Moody Clay loam	None	Same as H_1

wise broken up and subsequently cropped for a number of years. Eastern South Dakota soils selected for this study have been cropped for a period of 50 to 55 years.

In gathering samples an attempt was made to select virgin soils from fields which had not been pastured or cut for hay. In all cases, however, this was not possible. When the virgin field was located a sample was taken from a cultivated field lying immediately adjacent. The sample was then taken by carefully cutting a cube of soil to what appeared to be the normal depth of cultivation in that field. A sample was then taken in the same manner to the same depth from the virgin field. In order to eliminate any soil variation due to topography or factors other than cultivation, the samples of virgin and cultivated soils were selected from areas which were in close proximity.

Description of Soil Series

Barnes.—The Barnes series is a glacial soil. The surface of this soil ranges from black to brown in color to a depth of four to ten inches, resting on a brown soil to a depth of about 18 to 30 inches. Below this a characteristic grayish yellow layer is found. Pebbles and stones are found throughout the soil profile and large boulders may be found even at the surface. The surface soils as a rule do not effervesce with hydrochloric acid, and the lime in the deeper subsoil may be uniformly distributed through the material or may be collected into masses or concretions. (23)

Bearden.—The surface soil of the Bearden series is very dark grayish-brown friable, and finely granular. The surface soil grades into a brown friable subsurface soil which may be heavier than the surface soil. At about two feet in depth the granules disappear, and at from 18 to 22 inches the color changes to yellow. Between depths of about 39 to 48 inches bedded sand and gravel are present, above which a layer of highly calcareous structureless material containing numerous lime concretions occurs. This layer is from two to six inches thick. Some of the soils do not have the gravelly substratum and in this case no decided zone of lime accumulation occurs within three feet of the surface. (24).

Moody.—The surface covering of the Moody series is dark grayish-brown to a depth of about one inch. Grass roots are abundant in uncultivated soil. Underlying the surface layer is a dark grayish-brown soil to a depth of from 6 to 12 inches which in turn is underlain by a dark grayish-brown or almost black layer (the darkest layer of horizon A) to a depth of from 10 to 18 inches. The undisturbed material is slightly more firm than that of other layers and upon being broken up it becomes lighter in color. The fourth layer is non-calcareous and as a rule slightly heavier than the layers above, ranging in color from dark grayish-brown in the upper part to grayish-brown in the lower. Below a depth of from 30 to 40 inches is the zone of lime accumulation where the material is structureless and grayish-yellow in color. The Moody series is derived from the weathering of loess overlying glacial material at an average depth of about five feet. It rests on brown and gray mottled glacial till, and has a columnar structure. (24).

Williams.—The surface of Williams soil to a depth of about 7 to 12 inches consists of loose, friable, very dark grayish-brown or nearly black soil of finely granular structure. The surface soil is underlain to a depth varying from 16 to 20 inches by dark-brown or brown heavy textured soil containing glacial pebbles. The next layer, which reaches a depth of about 30 inches, is friable or slightly compact, yellow or grayish-yellow in color. It is highly calcareous, containing an abundance of lime in streaks and concretions. Some specks of orange or reddish-brown may be present in places. Below this is the pale yellow or yellow friable glacial till from which the soil was derived. (16).

Orman.—The surface soils of Orman series are brown and the subsoils brown or yellowish brown and both have the slaty tinge characteristic of the Pierre series. The series occurs on terraces within or bordering Pierre shale exposures and the material consists mainly of sediments from Pierre soils. The soils are sticky when wet and become very hard when dry. The topography is level and natural drainage is poor because of the impervious nature of the subsoil.

Pierre.—The soils of the Pierre series are light brown, brown or olive brown in color. They are compact and refractory when dry and very sticky when wet. The subsoils are brown to olive brown or slaty colored and are heavy in texture. They also grade into a substratum of partially weathered shale, usually below six feet. The topography is characteristic, consisting of rounded hills and ridges. Surface drainage is usually good. This series is of residual origin, being derived from Pierre shale by weathering.

Experimental Methods and Findings

The soil samples were taken carefully so as to avoid any mechanical change in structure. A representative portion of each sample was removed, air dried, finely ground, and set aside in capped bottles for use in the chemical analysis.

Consideration was given to the advisability of applying statistical methods to the data for making comparisons between the virgin and cultivated soils. However, on examination of the data, it appeared that there were distinct differences between soil types and locations with regard to the behavior of the paired samples. Therefore, as far as some of the analyses are concerned, negative differences in one or two locations might obviate positive differences in the remaining locations as in the case of the aggregate analyses and phosphorus.

A general comparison of virgin and cultivated soils would give a picture of the total area studied, but would not express the interactions between physical or chemical analyses and soil types or locations. Since only a single pair of samples was taken in a given location, it was impossible to make a statistical camparison within a location. In future studies of this kind, it would seem desirable to study a single area such as a county and take a larger number of samples in order to obtain a more precise comparison.

Physical Analysis

The structural analysis was made upon the unground samples as soon as possible after they were air dry. Several methods of determining structure have been suggested by various authors. Buehrer (9) suggests the use of the movement of gases through the soil as a measure of soil structure. Rhoades (18) suggests the use of the Kipecky type of elutraitor for the separation of different sizes of soil granules. Baver (3) suggests soil porosity as a measure of aggregation. Yoder (27) and Bouyoucos (5) offer methods based on the water stability of the soil aggregates.

Water stable aggregates are defined and accounted for by Bradfield (8) in his statement that, "In the undisturbed soil which is producing a heavy growth of perennial plants, especially the grasses, interfaces are created on the surface of the soil granules which differ from the interior of these particles. These interfaces are in many cases largely the products or by-products of the plant roots and the micro-organisms which feed upon these roots. The granules are often so dense that aerobic organisms probably thrive largely on the surface and not within the granule. If the soil is unmolested for a few years these organisms build up an interface that is fairly stable, our so-called 'water resistant' aggregates."

In this work the water stable aggregates were used as a criterion of structure. They were determined in two ways, one method being that of Bouyoucos (4), the other method being similar to that suggested by Yoder (27).

In the Bouyoucos method 50 grams of soil (air dry basis) was placed in a bag of two-millimeter window screen and the bag was suspended in a 1000 cc hydrometer cylinder filled with water to the proper mark. The bag was pushed up and down slowly in the water to remove slaked particles. After the soil was completely slaked, five cubic centimeters of normal potassium hydroxide was added and the soil was then shaken six times by placing one hand on the mouth of the cylinder and turning the latter completely upside down and back three times. Hydrometer readings were taken at 10, 30, and 60 seconds, and at 15 minutes. The weight of the soil within the various size classes was then determined by referring to the following table:

Time of Sedimentation	Largest diameter of particles in suspension
10 sec.	.1914 mm.
30 "	.11009 mm.
60 "	.07785 mm.
15 min.	.00259 mm.

In the Yoder method 50 grams of air dry soil was allowed to slake through a graded nest of screens immersed in a constant volume of water (four liters). The nests of screens were mechanically raised and lowered at a slow rate to facilitate slaking and separation of the various sized granules. The screens and soil were then dried and the soil was brushed out and the several size classes were weighed.

Structure stability has been measured by Bouyoucos by three methods. In one method he uses the time of slaking and structure of the slaked material as a measure (4). In another method he determines sructure stability of the existing aggregates by determining the moisture equivalent of water treated soil and soil treated with potassium chloride and comparing them (7). His third method (7) was used in this study. Two hundred cubic centimeter cylinders were filled to the 40 cubic centimeter mark with distilled water and with normal potassium chloride solution respectively. Fifteen grams of air dry soil was added to each cylinder. The soil was first gently loosened by gradually working an iron rod to the bottom of the cylinder and then it was stirred by moving the rod in a forward and backward position 20 times. This stirring was repeated three times at haif hour intervals, and the soils were then allowed to stand for 24 hours, at which time their settling volume was read. The difference in the settled volume with water and with potassium chloride solution was used as a measure of stability. Stable soils showed little difference.

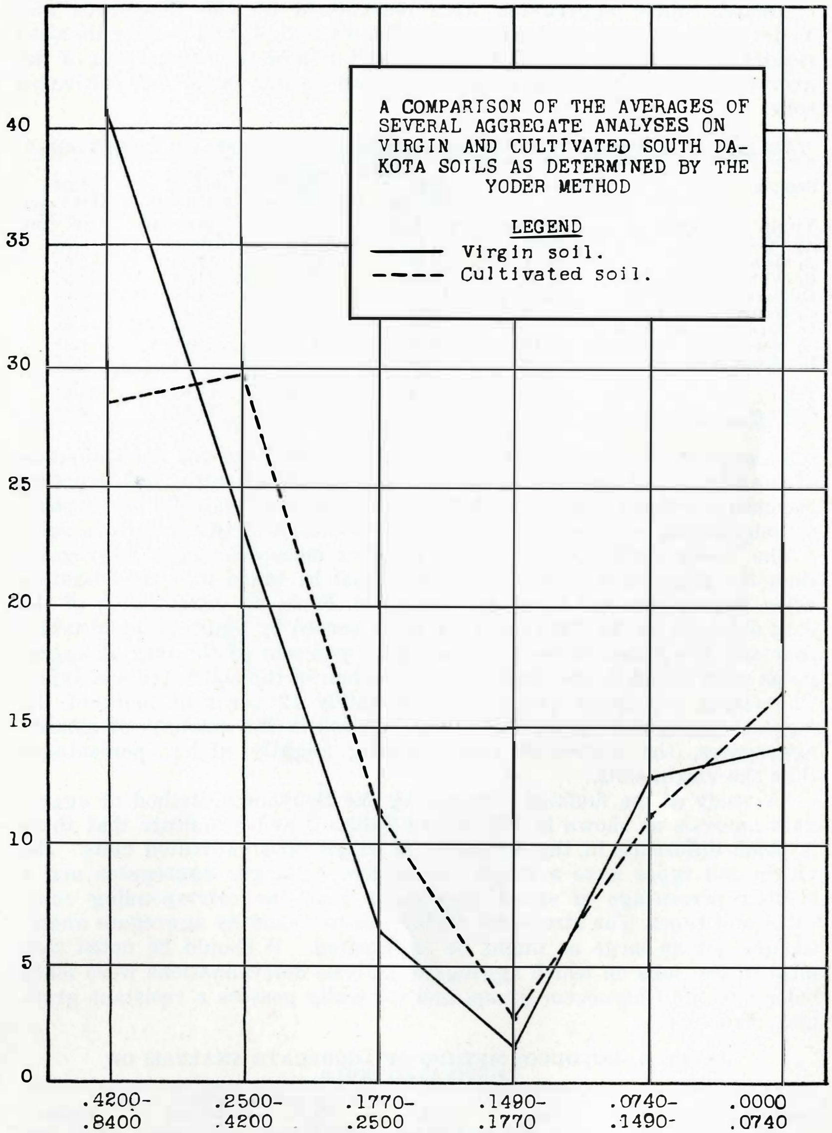
The mechanical analysis was done by the Bouyoucos (6) method.

Aggregate Analysis.—The cause of wind erosion in the Great Plains during recent years has been the subject of much speculation. Breakdown of structure due to cultivation has been suggested as a possible explanation. One theory which has been advanced is that the decrease in organic matter due to cultivation, together with the mechanical manipulation of the soil by tillage, has caused breakdown of structure. Bradfield (8) states that although they do not ensure favorable structure, calcium and organic matter do aid in the development of such structure. Work to be discussed later indicates a decrease in organic matter through cultivation. If organic matter is largely responsible for the granular nature of the soil, it would seem plausible that a reduction of the organic matter of the soil resulting from cultivation would likewise bring about structural changes in the soil, producing a finer state of aggregation or partial degranulation. The findings of this experiment do not correspond entirely with the above supposition.

In the process of sampling it was noted that in the soils studied the virgin soils showed a more coarsely granular structure and were more friable than the cultivated soils. The coarsely granular structure noted in the virgin soil is no doubt mechanically unstable because as soon as the soil is cultivated the larger aggregates probably break down to smaller aggregates such as exist in comparable cultivated soils. It might be presumed that in virgin soils the large visible aggregates, which are relatively unstable, consist of several smaller aggregates.

The methods used for determining the size of water stable aggregates are based on the assumption that the soil slakes into its ultimate state of aggregation. It would seem that soils in their natural cultivated state when exposed to rain and mechanical agitation by tillage, could be broken down to the same ultimate state as in the laboratory by aggregate analysis. However it is doubtful if soils in their natural state are ever completely broken down to their ultimate aggregation.

In the soil structure studies it was found that the most suitable method was the determination of water stable aggregates of various sizes since it seemed that this was the only uniform measurement which could be made.



(Size of Aggregate in Millimeters)

FIGURE 2

Water stable aggregates were determined by the Bouyoucos and Yoder methods discussed previously. Tables 2, 3, 4, and 5 show detailed results of the two methods. Figures 2 and 3 show the camparison of the averages of the several aggregate analyses on the virgin and cultivated soils.

TABLE 2.—BOUYOUCOS METHOD OF AGGREGATE ANALYSIS OF VIRGIN SOILS

Sample	Size of Aggregates in mm. Over .1914 mm.	.1914–.11009 mm.	.11009–.007785 mm.	.007785 .00259 mm.	.00259 .0000 mm.
Virgin Soil Type	per cent	per cent	per cent	per cent	per cent
A_1 Pierre Clay	82.32	5.00	1.00	8.28	3.40
B_1 Orman Clay	70.64	10.00	5.00	12.36	2.00
C_1 Williams Clay	71.60	9.00	5.00	11.84	2.56
D_1 Barnes Sandy loam	74.52	14.00	2.00	7.64	1.84
E_1 Bearden Silt loam	52.00	11.00	13.00	21.88	2.12
F_1 Barnes Sandy loam	76.16	7.00	8.00	4.28	4.56
G_1 Moody Silty Clay loam	67.12	8.00	6.56	14.92	3.40
H_1 Moody Clay loam	62.28	12.50	7.52	14.14	3.56
Total	556.64	76.50	48.08	95.34	23.44
Average	69.58	9.56	6.01	11.92	2.93

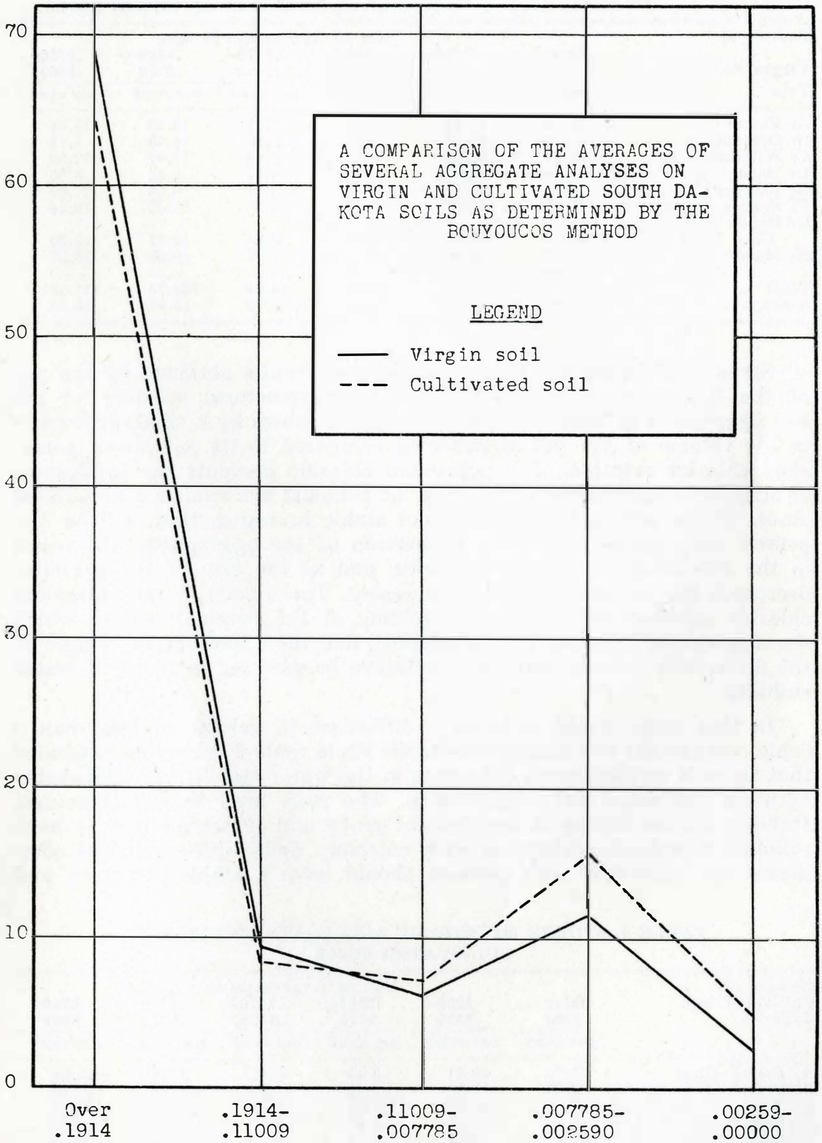
Because there is no universally accepted method for the determination of the size of soil aggregates, the accurate measurement of soil structure becomes a difficult problem. However, the methods available are capable of determining significant differences of structure between various soils.

The Yoder method of aggregate analysis measures larger aggregates than the Bouyoucos method, and this must be taken into consideration when figures two and three are examined. From an examination of the data obtained by the Yoder method as presented by figure two and tables four and five it can be seen that a higher per cent of the largest aggregates were found in the virgin soil types than in the cultivated soil types. The virgin soil types contain approximately 12 per cent more of the largest aggregates. Some difference is found in the amounts of smaller aggregates, the cultivated soils showing slightly higher percentages than the virgin soils.

A study of the findings obtained by the Bouyoucos method of aggregate analysis as shown in Fig. 3 and Tables 2 and 3 indicate that there is some difference in the structure of virgin and cultivated soils. The virgin soil types have a larger percentage of larger aggregates and a smaller percentage of small aggregates than the corresponding cultivated soil types. The structural differences as found by aggregate analysis are not as large as might be anticipated. It should be noted that most of the soils on which aggregate analysis determinations were made belong to the Chernozem group, and naturally possess a resistant granular structure.

TABLE 3.—BOYOUCOS METHOD OF AGGREGATE ANALYSIS OF CULTIVATED SOILS

Sample	Size of Aggregates in mm. Over .1914 mm.	.1914–.11009 mm.	.11009–.007785 mm.	.007785–.00259 mm.	.00259–.0000 mm.
Virgin Soil Type	per cent	per cent	per cent	per cent	per cent
A_2 Pierre Clay	58.32	10.00	12.00	16.00	3.68
B_2 Orman Clay	50.32	12.00	12.00	21.68	4.00
C_2 Williams Clay loam	67.60	8.00	4.00	15.28	5.12
D_2 Barnes Sandy loam	72.72	4.00	8.00	9.64	5.64
E_2 Bearden Clay loam	77.32	10.00	3.00	7.28	2.40
F_2 Barnes Sandy loam	76.38	5.00	4.00	9.78	4.84
G_2 Moody Silty Clay loam	62.12	8.00	6.00	19.20	4.68
H_2 Moody Clay loam	51.88	11.50	7.50	23.92	5.20
Total	516.66	68.50	56.50	122.78	35.56
Average	64.58	8.56	7.06	15.35	4.45



(Size of Aggregate in Millimeters)

FIGURE 3

TABLE 4.—YODER METHOD OF AGGREGATE ANALYSIS OF VIRGIN SOILS

Sample of Virgin Soil Type	Size of Aggregates in mm. Over .4200	.4200–.2500	.2500–.1770	.1770–.1490	.1490–.0740	.0740–.0000
	per cent	per cent	per cent	per cent	per cent	per cent
A_1 Pierre Clay	43.02	22.84	5.83	1.79	15.18	11.34
B_1 OrmanClay	42.79	21.76	8.22	3.80	14.68	8.75
C_1 Williams Clay	40.64	31.13	3.08	0.63	11.97	12.55
D_1 Barnes Sandy loam	42.98	35.32	2.97	0.65	9.42	8.66
E_1 Bearden Silt loam	44.71	16.08	12.12	2.01	8.06	17.02
F_1 Barnes Sandy loam	28.93	25.34	8.30	2.55	15.42	19.46
G_1 Moody Silty Clay loam	36.89	21.80	5.96	0.84	19.21	15.30
H_1 Moody Clay loam	47.41	14.35	8.35	1.77	9.85	18.27
Total	327.37	188.62	54.83	14.04	103.79	111.35
Average	40.92	23.58	6.85	1.76	12.97	13.92

Structural Stability.—Table 6 shows the results obtained by the use of the Bouyoucos method for determining structural stability of the soil aggregates in water. Stable structure is shown by a small difference in the volume of the soil in water as compared to its volume in potassium chloride solution. The potassium chloride prevents the breakdown of structural aggregates by keeping the colloidal material in a flocculated state. If the soil aggregates are not stable in water, they will be dispersed when placed in water. Dispersion of the aggregates will result in the formation of smaller granules, and as the size of the granules decreases the volume of the soil increases. Those soils in the potassium chloride solution will retain the volume of the original soil in which the aggregates have not been dispersed, and the difference in volume of the differently treated soils can therefore be used as an index of water stability.

In this study a soil showing a difference in volume of less than 2 cubic centimeters was considered stable. From table 6 it may be concluded that there is no significant difference in the water stability of aggregates between cultivated and virgin soils. The soils used in the structural stability studies belong in the Pedocal group and consequently they have colloidal complexes staturated with calcium. Soils whose colloidal complexes are saturated with calcium should have a stable structure and

TABLE 5.—YODER METHOD OF AGGREGATE ANALYSIS OF CULTIVATED SOILS

Sample of Cultivated Soil Type	Size of Aggregates in mm. Over .4200	.4200–.2500	.2500–.1770	.1770–.1490	.1490–.0740	.0740–.0000
	per cent	per cent	per cent	per cent	per cent	per cent
A_2 Pierre Clay	31.79	43.31	3.45	0.65	8.14	12.66
B_2 Orman Clay	4.59	19.36	28.41	11.64	15.90	20.10
C_2 Williams Clay loam	26.37	32.46	8.22	1.77	14.02	17.16
D_2 Barnes Sandy loam	33.19	33.13	3.35	1.30	14.77	14.26
E_2 Bearden Clay loam	38.21	18.59	13.09	0.95	10.95	18.21
F_2 Barnes Sandy loam	38.62	29.04	7.68	1.54	8.10	15.02
G_2 Moody Silty Clay loam	27.74	50.16	2.04	0.85	7.35	11.86
H_2 Moody Clay loam	24.33	13.15	24.63	2.24	12.67	22.98
Total	224.84	239.20	90.87	20.94	91.90	132.25
Average	28.10	29.90	11.36	2.61	11.50	16.53

TABLE 6—STUDY OF STABILITY OF AGGREGATES OF VIRGIN AND CULTIVATED SOILS BY THE BOUYOUCOS METHOD

Sample	Soil Type	Volume in Water cc.	Volume in KCL soln. cc.	Difference in Volume cc.
A_1	Pierre Clay	18.5	17.0	1.5
A_2	Pierre Clay	16.0	16.0	0.0
B_1	Orman Clay	17.3	16.8	0.5
B_2	Orman Clay	17.0	16.5	0.5
C_1	Williams Clay	18.5	18.0	0.5
C_2	Williams Clay loam	16.5	17.0	−0.5
D_1	Barnes Sandy loam	16.0	16.0	0.0
D_2	Barnes Sandy loam	14.0	14.0	0.0
E_1	Bearden Silt loam	20.3	21.8	−1.5
E_2	Bearden Clay loam	17.8	17.3	0.5
F_1	Barnes Sandy loam	19.5	19.5	0.0
F_2	Barnes Sandy loam	15.5	16.0	−0.5
G_1	Moody Silty Clay loam	17.5	18.0	−0.5
G_2	Moody Silty Clay loam	17.3	17.3	0.0
H_1	Moody Clay loam	20.5	20.5	0.0
H_2	Moody Clay loam	17.3	17.3	0.0

resist any mechanical breakdown when placed in water. The results obtained in the structural stability studies agree with the above facts since all the soils possessed a water stable structure. Cultivation had little or no effect on the water stability of the granules. It may have been assumed that the loss of organic matter would have some effect on the stability of the granules because of the decrease in the amount of humus and consequent decrease in the organic colloids which together with inorganic colloids are considered responsible for binding the soil particles into granules. It may be presumed that the humus or organic colloids remaining in the soil are sufficient to stabilize the soil granules against the dispersing or degranulating effects of water to which the soils are subjected in the Bouyoucos method for determining water stability.

In the Bouyoucos method for determining state of aggregation of the soils, 50 grams of soil was allowed to slake through a 2 mm. mesh screen by slowly lowering and raising the soil and screen in 1000 cc of water. The time required for the soil to pass through the screen is considered the time required to slake. The following results were obtained.

Virgin Soil Sample	Virgin Soil Time to Slake in Minutes	Cultivated Soil Sample	Cultivated Soil Time to Slake in Minutes
A_1	10	A_2	1
B_1	3	B_2	1
C_1	10	C_2	12
D_1	19	D_2	5
E_1	16	E_2	14
F_1	13	F_2	5
G_1	12	G_2	9
H_1	28	H_2	5

The results of the slaking experiment show that the virgin soils require an average of 13.9 minutes to slake and the cultivated soils require an average of 6.5 minutes. This difference may be attributed in part to the presence of roots in the virgin soil which tend to hold the soil together.

Mechanical Analysis.—Daniel (1) made several mechanical analyses to compare virgin and cropped with drift soil in the Southern High Plains. He found very little difference in the sand, silt, and clay content of virgin and cultivated soil.

From Table 7 it may be observed that the cultivated clay soils contain less clay and more sand than the virgin clay soils, the silt varying each way. Soils having a lower clay content show increased clay percentages in the cultivated soils.

TABLE 7.—MECHANICAL ANALYSIS OF VIRGIN AND CULTIVATED SOILS

Sample	Sand per cent	Silt per cent	Clay per cent	Class	$\frac{\text{Sand \& Silt}}{\text{Clay}}$
A_1	24.98	27.82	47.20	Clay	1.119
A_2	25.60	30.04	44.36	Clay	1.254
B_1	18.00	24.72	57.28	Clay	0.746
B_2	18.52	26.20	55.28	Clay	0.809
C_1	23.60	44.84	31.56	Clay	2.169
C_2	34.16	39.56	26.28	Clay loam	2.805
D_1	57.44	23.36	19.20	Sandy loam	4.208
D_2	56.96	23.68	19.36	Sandy loam	4.165
E_1	30.96	50.84	18.20	Silt loam	4.495
E_2	39.48	38.40	22.12	Clay loam	3.521
F_1	60.84	28.60	10.56	Sandy loam	8.470
F_2	64.18	19.10	16.72	Sandy loam	4.981
G_1	23.88	55.20	20.92	Silty clay loam	3.780
G_2	22.26	52.62	25.12	Silty clay loam	2.981
H_1	35.86	42.22	21.92	Clay loam	3.562
H_2	32.16	40.08	27.76	Clay loam	2.602

Fig. 4 shows a comparison of the $\frac{\text{sand} + \text{silt}}{\text{clay}}$ ratios of the virgin and cultivated soils. It is possible that there may have been some slight variation in the original textures of the cultivated and virgin soils of a pair, i. e., before the sod was broken the soil at the location from which the cultivated sample was taken may have varied to a slight extent in texture from the soil at the location where the virgin sample was taken. However, the samples were taken in such close proximity that variations as large as are indicated by the analysis could not be due to this factor alone.

In the soils of coarser texture the increase in clay content is probably due to the fact that percolation of water through the soil has carried the finer materials from the surface downward. Erosion of the surface soil, and cultivation would then result in the mixing of the surface with the subsurface soils which contain a higher per cent of clay. In the clay soils, because of their impervious nature and because they lie in an area of such low rainfall, removal of clay from the surface by mechanical eluviation to the subsurface has not occurred to any great extent. Erosion by wind tends to remove from these clay soils a larger per cent of clay than of silt and sand, causing the increased $\frac{\text{sand} + \text{silt}}{\text{clay}}$ ratio.

Chemical Analysis

Method of Analysis.—Moisture was determined on the ground soil sample by heating at 110 degrees Centigrade for 24 hours. Loss on igni-

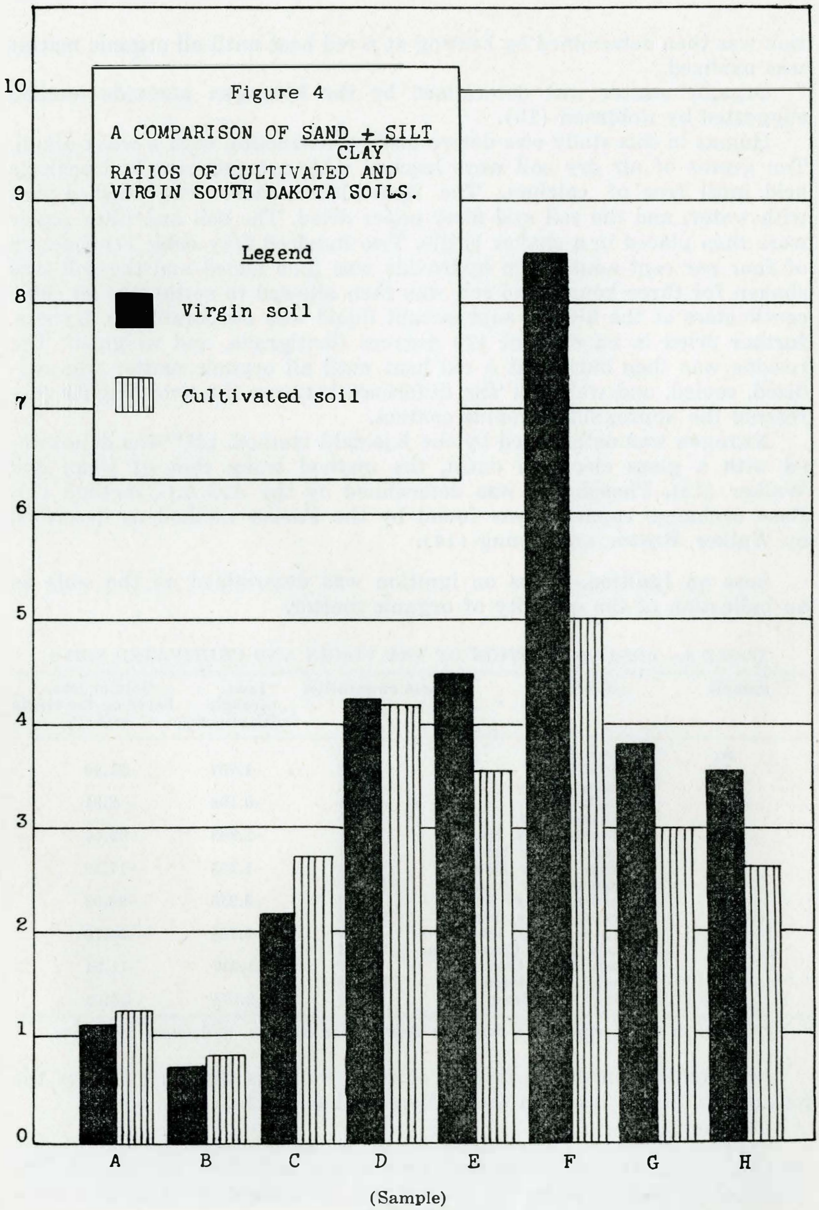


Figure 4
A COMPARISON OF SAND + SILT / CLAY RATIOS OF CULTIVATED AND VIRGIN SOUTH DAKOTA SOILS.
Legend
Virgin soil
Cultivated soil
0
1
2
3
4
5
6
7
8
9
10
A
B
C
D
E
F
G
H
(Sample)

FIGURE 4

tion was then determined by heating at a red heat until all organic matter was oxidized.

Organic matter was determined by the hydrogen peroxide method suggested by Robinson (15).

Humus in this study was determined by extraction with a weak alkali. Ten grams of air dry soil were leached with one per cent hydrochloric acid until free of calcium. The hydrochloric acid was washed out with water, and the soil and filter paper dried. The soil and filter paper were then placed in a shaker bottle. Two hundred fifty cubic centimeters of four per cent ammonium hydroxide was then added and the soil was shaken for three hours. The soil was then allowed to settle and 50 cubic centimeters of the filtered supernatant liquid was evaporated to dryness, further dried in an oven at 110 degrees Centigrade, and weighed. The residue was then burned at a red heat until all organic matter was oxidized, cooled, and weighed. The difference between the two weights represents the approximate humus content.

Nitrogen was determined by the Kjeldahl method. pH* was determined with a glass electrode outfit, the method being that of Dean and Walker (12). Phosphorus was determined by the A.O.A.C. method (1). Base exchange capacity was found by the Parker method as described by Walker, Brown, and Young (14).

Loss on Ignition.—Loss on ignition was determined on the soils as an indication of the quantity of organic matter.

TABLE 8.—LOSS ON IGNITION OF THE VIRGIN AND CULTIVATED SOILS

Sample	Soil Type	Loss on ignition %	Loss through Cultivation* %	Gain or loss, based on the virgin soils* %
A_1	Pierre Clay	7.795		
A_2	Pierre Clay	6.088	–1.707	–21.90
B_1	Orman Clay	6.742		
B_2	Orman Clay	6.546	–0.196	– 2.91
C_1	Williams Clay	8.859		
C_2	Williams Clay loam	6.871	–1.988	22.44
D_1	Barnes Sandy loam	6.657		
D_2	Barnes Sandy loam	5.492	–1.165	–17.50
E_1	Bearden Silt loam	11.829		
E_2	Bearden Clay loam	8.514	–3.315	–28.02
F_1	Barnes Sandy loam	10.772		
F_2	Barnes Sandy loam	4.987	–5.785	–53.70
G_1	Moody Silty Clay loam	10.194		
G_2	Moody Silty Clay loam	8.977	–1.217	–11.94
H_1	Moody Clay loam	11.182		
H_2	Moody Clay loam	8.608	–2.574	–23.02

* Gains, in tables similar to this, are represented by plus, and losses by minus.

An examination of the figures of table 8 shows that in all cases the loss on ignition is lower in the cultivated than in the virgin soil.

Organic Matter.—The importance of the amount and quality of soil organic matter in relation to crop growth has long been recognized. The functions of organic matter in the soil may be classed as physical, chemical, biological, and biochemical.

* The term pH is a mathematical expression used to denote the degree of acidity or alkalinity. A pH of 7 represents a neutral reaction, below pH7 an acid reaction, and above pH7, an alkaline reaction.

The physical effects of organic matter upon soil are extremely complex. From the physical standpoint organic matter affects the properties of soil in the following respects: weight, cohesion, structure, absorption, porosity, color, temperature and tilth. Any change in the amounts of organic matter in the soil may affect one or all of the above physical properties. The present study has attempted to correlate the loss of organic matter with structural changes in the soil.

The chemical, biological, and biochemical effects of organic matter are of considerable importance from the standpoint of soil fertility. Chemically organic matter functions in three important ways, namely: (1) organic matter constitutes the most valuable source of soil nitrogen; (2) through biochemical changes or decomposition of organic matter mineral plant food is made available; (3) organic matter functions in base exchange and other soil reactions. It is obvious that losses of soil organic matter will have a decided influence upon soil fertility and consequently affect crop production.

A study of table 9 reveals that losses of organic matter resulted in all eight of the cultivated soils studied. The loss of organic matter was found to be greater than the loss of any other soil constituent determined in this study. The average loss of organic matter through cultivation was approximately 42 per cent of the amount contained in the virgin soil. These figures indicate that during the relatively short period in which South Dakota soils have been cropped almost one-half of the original organic matter has been depleted.

TABLE 9.—THE ORGANIC MATTER CONTENT OF VIRGIN AND CULTIVATED SOILS

Sample	Soil Type	[redacted] %	Loss through Cultivation* %	Gain or loss, based on the virgin soils* %
A_1	Pierre Clay	3.706		
A_2	Pierre Clay	2.386	–1.320	–35.62
B_1	Orman Clay	2.478		
B_2	Orman Clay	1.399	–1.079	–43.54
C_1	Williams Clay	5.978		
C_2	Williams Clay loam	3.889	–2.089	–34.94
D_1	Barnes Sandy loam	4.035		
D_2	Barnes Sandy loam	3.202	–0.833	–20.64
E_1	Bearden Silt loam	9.060		
E_2	Bearden Clay loam	4.707	–4.353	–48.05
F_1	Barnes Sandy loam	9.573		
F_2	Branes Sandy loam	3.363	–6.210	–64.87
G_1	Moody Silty Clay loam	6.455		
G_2	Moody Silty Clay loam	4.912	–1.543	–23.90
H_1	Moody Clay loam	9.472		
H_2	Moody Clay loam	5.404	–4.068	–42.95

* Gains, in tables similar to this, are represented by plus, and losses by minus

From the structural studies it was concluded that cultivation caused little change in the soil structure. Losses in organic matter, however, have been shown to be large. These two facts are not in agreement with the ordinary conception of the relationship which exists between organic matter and structure.

The determination of the effect of the quantity of organic matter in the soil upon the soil structure involves certain difficulties. It is entirely possible that a certain definite quantity or percentage of organic matter brings about the production of the highest state of granulation as measured by the size or stability of the granules. From a study of the results obtained it might be concluded that the reduction in organic matter due to cultivation has not been large enough to have a decided influence upon the size and stability of the granules, but that it may be the cause of decreased resistance to water slaking found by the Bouyoucus method for determining soil structure.

Humus.—The humus fraction of the organic matter was considered to be that portion of the organic matter which is soluble in a weak base.

Humus on samples A an B was not determined because of the effect upon the results by the high colloidal content of the soils.

TABLE 10.—THE HUMUS CONTENT OF VIRGIN AND CULTIVATED SOILS

Sample	Soil Type	Humus %	Loss through cultivation %	Loss based on the humus content of the virgin soil %
C_1	Williams Clay	5.110		
C_2	Williams Clay loam	2.645	2.465	48.24
D_1	Barnes Sandy loam	2.870		
D_2	Barnes Sandy loam	2.575	0.295	10.28
E_1	Bearden Silt loam	5.285		
E_2	Bearden Clay loam	3.870	1.415	26.77
F_1	Barnes Sandy loam	4.255		
F_2	Barnes Sandy loam	2.333	1.922	45.12
G_1	Moody Silty Clay loam	3.770		
G_2	Moody Silty Clay loam	3.515	0.255	6.76
H_1	Moody Clay loam	3.765		
H_2	Moody Clay loam	2.810	0.955	25.37

In the six soils shown in table 10 losses in humus were found in all cases, the average loss being 29.163 per cent, when the humus content of the virgin soil was used as the basis for computing the losses.

Nitrogen.—The results of the nitrogen determinations on the cultivated and virgin soils are shown in Table 11.

TABLE 11.—THE NITROGEN CONTENT OF VIRGIN AND CULTIVATED SOILS

Sample	Soil Type	Nitrogen %	Gain or loss through cultivation %	Gain or loss based on the virgin soil %
A_1	Pierre Clay	0.1877		
A_2	Pierre Clay	0.1267	–0.0610	–32.50
B_1	Orman Clay	0.1200		
B_2	Orman Clay	0.1106	–0.0094	– 7.83
C_1	Williams Clay	0.2624		
C_2	Williams Clay loam	0.1798	–0.0826	–31.48
D_1	Barnes Sandy loam	0.1869		
D_2	Barnes Sandy loam	0.1494	–0.0375	–20.06
E_1	Bearden Silt loam	0.4090		
E_2	Bearden Clay loam	0.2690	–0.1400	–34.23
F_1	Barnes Sandy loam	0.3795		
F_2	Barnes Sandy loam	0.1555	–0.2240	–59.03
G_1	Moody Silty Clay loam	0.3251		
G_2	Moody Silty Clay loam	0.2760	–0.0491	–15.10
H_1	Moody Clay loam	0.4059		
H_2	Moody Clay loam	0.2739	–0.1320	–32.52

A loss in nitrogen occurred in every case as the result of cultivation. The average loss for all soils, using virgin soil as the base, is about 29 per cent, indicating that unless cultural practices are changed South Dakota farmers will within a relatively short period have confronting them the additional problem of nitrogen shortage. From Fig. 5 it will be seen that losses in nitrogen and loss on ignition are similar, the percentage losses in nitrogen being slightly larger in all cases. Losses in humus and organic matter also correspond closely with losses in nitro-

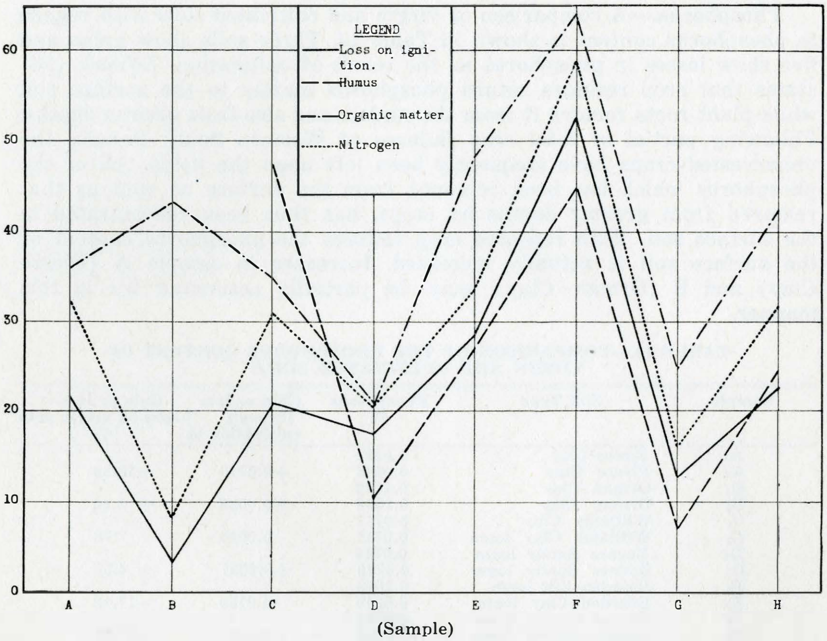


FIGURE 5

A COMPARISON OF PERCENTAGE LOSSES IN HUMUS, ORGANIC MATTER, LOSS ON IGNITION AND NITROGEN DUE TO CULTIVATION OF SOUTH DAKOTA SOILS

gen. A study of Table 12 reveals that the organic matter-nitrogen ratio (total organic matter divided by the nitrogen) is wider in the virgin soil than in the cultivated soils. This would indicate that soils lose organic matter at a more rapid rate than they lose nitrogen.

TABLE 12.—A COMPARISON OF THE ORGANIC MATTER, NITROGEN, AND HUMUS CONTENT OF THE VARIOUS SOILS; AND THE ORGANIC MATTER-NITROGEN RATIOS OF THE VIRGIN AND CULTIVATED SOILS

Sample	Soil Type	Organic Matter %	Nitrogen %	Organic Matter divided by Nitrogen	Humus %
A_1	Pierre Clay	3.706	.1877	19.744	
A_2	Pierre Clay	2.386	.1267	18.832	
B_1	Orman Clay	1.870	.1200	15.583	
B_2	Orman Clay	1.102	.1106	9.964	
C_1	Williams Clay	5.978	.2624	22.782	5.110
C_2	Williams Clay loam	3.889	.1798	21.630	2.645
D_1	Barnes Sandy loam	4.035	.1869	21.589	2.870
D_2	Barnes Sandy loam	3.202	.1494	21.432	2.575
E_1	Bearden Silt loam	9.060	.4090	22.152	5.285
E_2	Bearden Clay loam	4.707	.2690	17.498	3.870
F_1	Barnes Sandy loam	9.573	.3795	25.225	4.255
F_2	Barnes Sandy loam	3.363	.1555	21.627	2.333
G_1	Moody Silty Clay loam	6.455	.3251	19.855	3.770
G_2	Moody Silty Clay loam	4.912	.2760	17.797	3.515
H_1	Moody Clay loam	9.472	.4059	23.336	3.765
H_2	Moody Clay loam	5.404	.2739	19.730	2.810

Phosphorus.—A comparison of virgin and cultivated soils with regard to phosphorus content is shown in Table 13. Three soils show gains and five show losses in phosphorus as the result of cultivation. DeTurk (13) states that crop residues return phosphorus mainly to the surface soil while plant roots remove it from the surface and also from greater depths. Following partial or total crop failures of Western South Dakota, the unharvested crops have frequently been left upon the fields. All of the phosphorus which has been removed from the surface as well as that removed from greater depths by crops, has thus been concentrated in the surface soil. With repeated crop failures the phosphorus content of the surface soil is actually increased. Increases in sample A (Pierre Clay) and B (Orman Clay) may be partially accounted for in this manner.

TABLE 13.—COMPARISON OF THE PHOSPHORUS CONTENT OF VIRGIN AND CULTIVATED SOILS

Sample	Soil Type	Phosphorus %	Gain or loss through cultivation %	Gain or loss, based on virgin soin %
A_1	Pierre Clay	0.0832		
A_2	Pierre Clay	0.0942	+0.0110	+13.22
B_1	Orman Clay	0.1028		
B_2	Orman Clay	0.1053	+0.0025	+ 2.43
C_1	Williams Clay	0.0771		
C_2	Williams Clay loam	0.0711	-0.0060	- 7.78
D_1	Barnes Sandy loam	0.0746		
D_2	Barnes Sandy loam	0.0783	+0.0037	+ 4.95
E_1	Bearden Silt loam	0.1098		
E_2	Bearden Clay loam	0.0910	-0.0188	-17.12
F_1	Barnes Sandy loam	0.0793		
F_2	Barnes Sandy loam	0.0493	-0.0300	-37.83
G_1	Moody Silty Clay loam	0.1126		
G_2	Moody Silty Clay loam	0.1093	-0.0033	- 2.93
H_1	Moody Clay loam	0.1181		
H_2	Moody Clay loam	0.0970	-0.0211	-17.87

In only one case, sample D, was the phosphorus content of the cultivated soil higher than the virgin soil in the Chernozems (dark-colored soil) of eastern South Dakota. In all other cases the phosphorus content of the soil has been decreased as the result of cultivation. The average decrease in phosphorus for the eastern South Dakota soils is 13.1 per cent. The largest loss of phosphorus was found in sample F, which is a sandy loam.

Soil Reaction.—The reaction of the soils was determined as pH with a glass electrode potentiometer. From Table 14 it is evident that in the eastern South Dakota soils the pH has been decreased (acidity increased) as the result of cultivation in all cases except one (sample D) where it remained constant. In the soils from western and central South Dakota small increases are noted in samples B and C. In samples A and B the calcium carbonate occurs fairly near the surface in large enough amounts to effervesce with hydrochloric acid. In sample C the zone of calcium carbonate occurs fairly near the surface. Thus, with plowing, an increase in pH might be expected as the result of mixing of the horizons. The high root content of the virgin soil may act also in giving it a lower pH than the cultivated soil. In eastern South Dakota the rainfall is great enough so that the calcium carbonate layer is considerably deeper beneath the surface of the soil. The mixing of the horizons by cultivation to the ordinary depths would not cause decreased acidity.

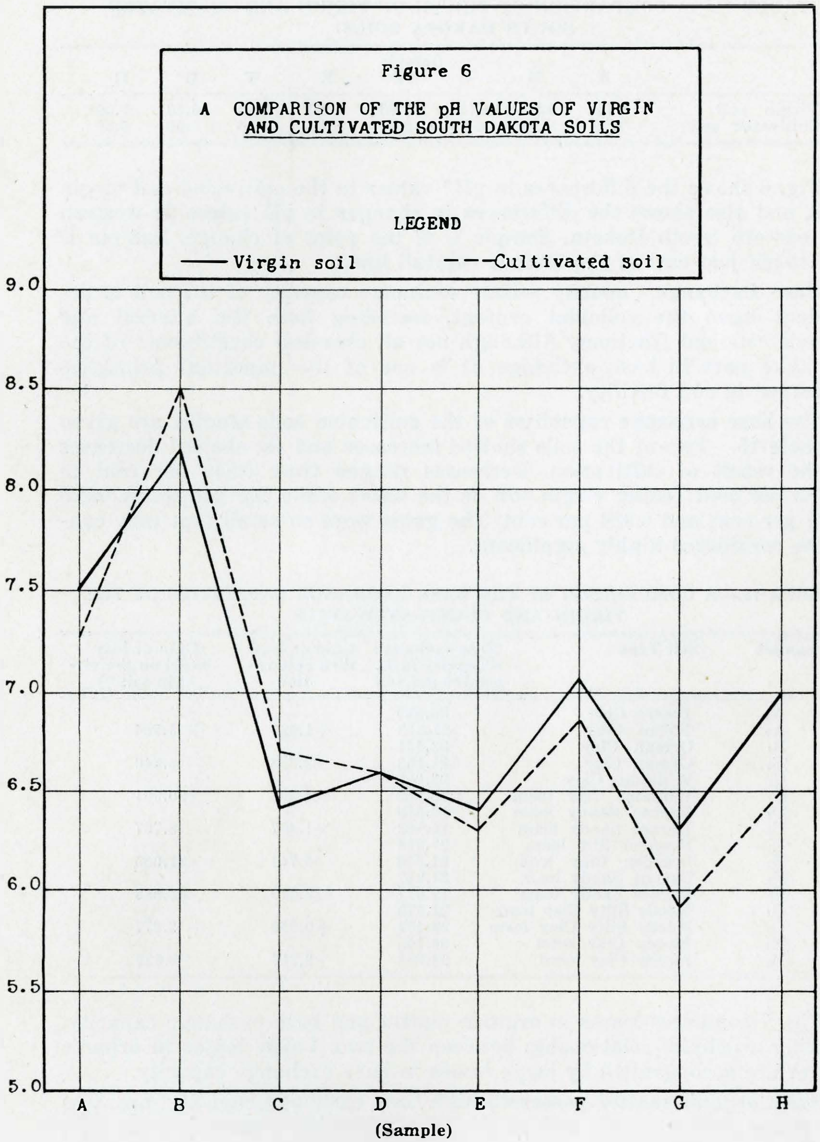


Figure 6
A COMPARISON OF THE pH VALUES OF VIRGIN AND CULTIVATED SOUTH DAKOTA SOILS
LEGEND
Virgin soil
Cultivated soil
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
A
B
C
D
E
F
G
H
(Sample)

FIGURE 6

TABLE 14.—A COMPARISON OF THE pH OF VIRGIN AND CULTIVATED SOUTH DAKOTA SOILS

	Sample A	B	C	D	E	F	G	H
Virgin soil	7.50	8.20	6.40	6.60	6.40	7.10	6.30	7.00
Cultivated soil	7.25	8.50	6.70	6.60	6.30	6.85	5.90	6.50

Fig. 6 shows the differences in pH* values in the cultivated and virgin soils, and also shows the differences in changes in pH values in western and eastern South Dakota. Sample D is the point of change. Sample D was taken just east of the 20-inch rainfall line.

Base Exchange Capacity.—Base exchange capacity of the soil is dependent upon the colloidal content, including both the mineral and organic colloidal fractions. Although not all chemical constituents of the soil take part in base exchange, it is one of the important principles concerned in soil fertility.

The base exchange capacities of the cultivated soils studied are given in Table 15. Two of the soils showed increases and six showed decreases as the result of cultivation. Decreases ranged from 6.840 per cent to 48.383 per cent (using virgin soil as the base) while the two gains were 3.677 per cent and 5.984 per cent. The gains were so small that they cannot be considered highly significant.

TABLE 15.—A COMPARISON OF THE BASE EXCHANGE CAPACITIES OF THE VIRGIN AND CULTIVATED SOILS

Sample	Soil Type	Base exchange Capacity M.E. per 100 gm.soil	Gain or loss thru cultivation	Gain or loss based on the virgin soil %
A_1	Pierre Clay	25.833		
A_2	Pierre Clay	27.353	+1.520	+ 5.884
B_1	Orman Clay	33.451		
B_2	Orman Clay	31.163	-2.288	- 6.840
C_1	Williams Clay	23.358		
C_2	Williams Clay loam	18.462	-4.896	-20.961
D_1	Barnes Sandy loam	16.619		
D_2	Barnes Sandy loam	15.162	-1.457	- 8.767
E_1	Bearden Silt loam	27.254		
E_2	Bearden Clay loam	21.513	-5.741	-21.065
F_1	Barnes Sandy loam	24.947		
F_2	Barnes Sandy loam	12.877	-12.070	-48.383
G_1	Moody Silty Clay loam	22.572		
G_2	Moody Silty Clay loam	23.402	+0.830	+ 3.677
H_1	Moody Clay loam	26.155		
H_2	Moody Clay loam	23.898	-2.257	-8.629

Fig. 7 compares losses in organic matter and base exchange capacity, showing a definite relationship between the two. Large losses in organic matter are accompanied by large losses in base exchange capacity.

Since organic matter possesses high base exchange capacity, any loss of organic matter would reduce the base exchange capacity of the soil.

The correlation between the base exchange capacity and the organic matter content are consistent with the generally accepted fact that organic colloids are dynamic factors in base exchange capacity.

* See footnote, page 20.

TABLE 16.—THE CHEMICAL ANALYSIS OF THE VARIOUS SOILS USED IN THE STUDY

Sample	Soil Type	Moisture %	Loss on Ignition %	Humus %	Organic Matter %	pH	Phosphorus %	Nitrogen %	Base Exchange Capacity ME.per 100 gm. soil
A_1	PierreCl ay	3.800	7.795		3.706	7.50	.0832	.1877	25.833
A_2	Pierre Clay	3.385	6.088		2.386	7.25	.0942	.1267	27.353
B_1	Orman Clay	4.295	6.742		2.478	8.20	.1028	.1200	33.451
B_2	Orman Clay	3.835	6.546		1.399	8.50	.1053	.1106	31.163
C_1	Williams Clay	2.900	8.859	5.110	5.987	6.40	.0771	.2624	23.358
C_2	Williams Clay loam	1.895	6.871	2.645	3.889	6.70	.0711	.1798	18.462
D_1	Barnes Sandy loam	2.600	6.657	2.870	4.035	6.60	.0746	.1869	16.619
D_2	Barnes Sandy loam	2.560	5.492	2.575	3.202	6.60	.0783	.1494	15.162
E_1	Bearden Silt loam	2.105	11.829	5.285	9.060	6.40	.1098	.4090	27.254
E_2	Bearden Clay loam	1.645	8.514	3.870	4.707	6.30	.0910	.2690	21.513
F_1	Barnes Sandy loam	1.860	10.772	4.255	9.573	7.10	.0793	.3795	24.947
F_2	Barnes Sandy loam	0.975	4.987	2.333	3.363	6.85	.0493	.1555	12.877
G_1	Moody Silty Clay loam	2.240	10.194	3.770	6.455	6.30	.1126	.3251	22.572
G_2	Moody Sitly Clay loam	2.595	8.977	3.515	4.912	5.90	.1093	.2760	23.402
H_1	Moody Clay loam	2.400	11.182	3.765	9.472	7.00	.1181	.4059	26.155
H_2	Moody Clay loam	2.380	8.608	2.810	5.404	6.50	.0970	.2739	23.898

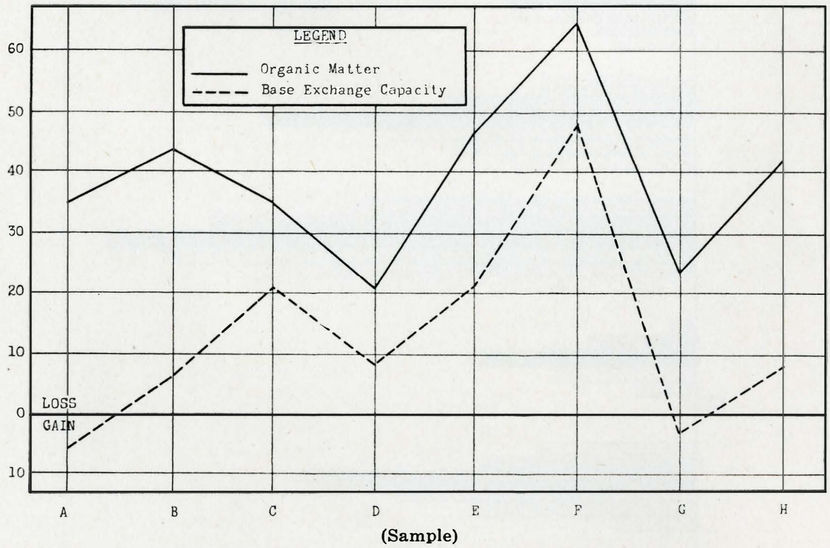


FIGURE 7

A COMPARISON OF THE REDUCTION IN BASE EXCHANGE CAPACITY AND LOSS OF ORGANIC MATTER OF CULTIVATED SOUTH DAKOTA SOILS

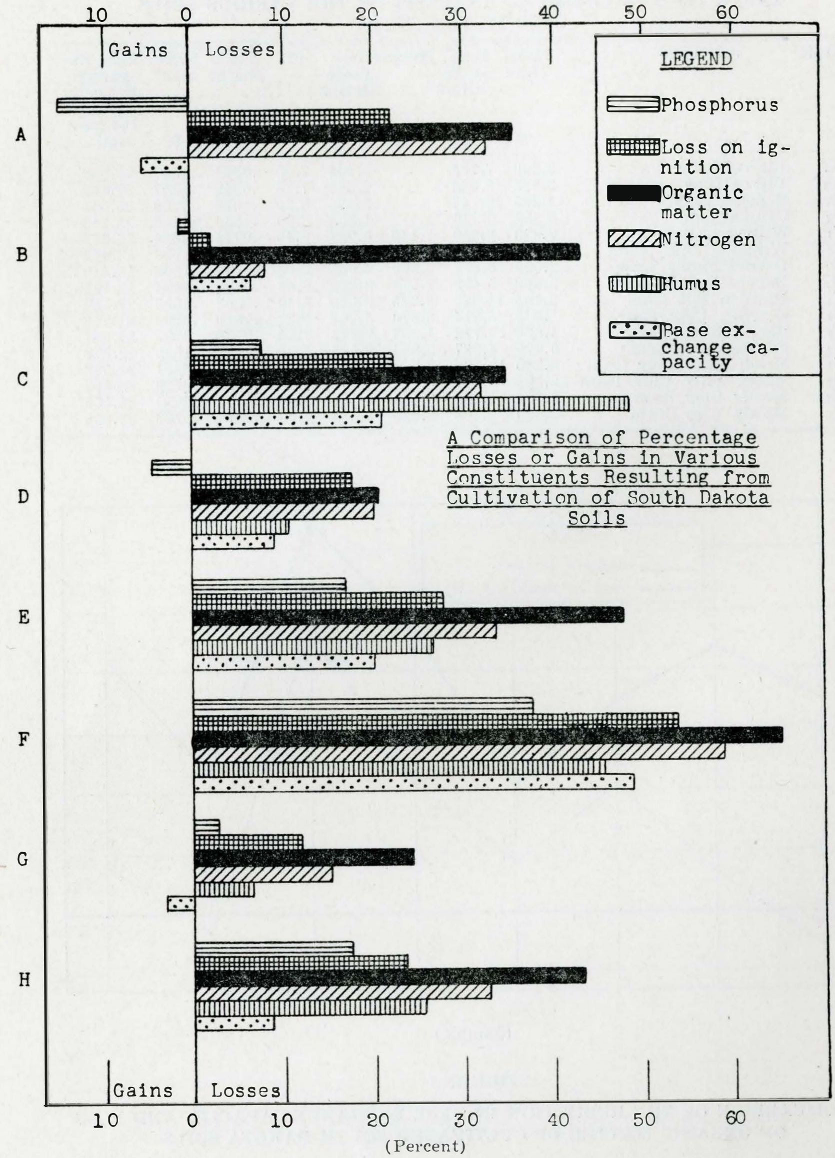

10
0
10
20
30
40
50
60
Gains
Losses
LEGEND
Phosphorus
Loss on ignition
Organic matter
Nitrogen
Humus
Base exchange capacity
A
B
C
D
E
F
G
H
A Comparison of Percentage Losses or Gains in Various Constituents Resulting from Cultivation of South Dakota Soils
Gains
Losses
10
0
10
20
30
40
50
60
(Percent)

FIGURE 8

Summary

1. The structural analysis of the virgin and cultivated soils, as determined by the Bouyoucous and Yoder Methods, show that cultivation has not had a pronounced effect upon soil structure. There were no highly significant differences in the distribution of the various sizes of the soil aggregates, as measured by the Bouyoucos or Yoder method, in either the virgin or cultivated soils. Some breakdown of structure was evidenced by the higher per cent of the larger aggregates and the lower per cent of smaller aggregates in the virgin soil, according to the results of both methods.
2. Structural stability of aggregates, as measured by the Bouyoucos method was found to be the same in virgin and in cultivated soils, but cultivated soils showed a tendency toward more rapid slaking in water than did virgin soils.
3. Losses in humus and loss on ignition occurred in the cultivated soils in every case.
4. Organic matter is known to aid in the development of good soil structure. An average loss of 42 per cent of the original organic matter resulted from cultivation in the soils which were studied. With such large losses of organic matter changes in structure would be anticipated. Since marked changes in structure were not found, it appears that while organic matter may be necessary in the development and maintenance of favorable structure, its value diminishes after the soil has acquired sufficient organic matter for the development of maximal structure. In the virgin soils, the larger amounts of organic matter were probably responsible for the increased time of slaking.
5. The mechanical analyses showed that little change in the texture of the soils has been brought about by cultivation. In three clay soils studied, a slight increase in the $\frac{\textbf{sand} + \textbf{silt}}{\textbf{clay}}$ ratio resulted. All other soils showing slight decreases in the $\frac{\textbf{sand} + \textbf{silt}}{\textbf{clay}}$ ratios of the cultivated soils.
6. Cultivation resulted in a decrease in base exchange capacity in all soils studied with the exception of two. Since these two represent relatively small increases as compared with the decreases, it may be that original differences in the soil were responsible for the apparent discrepancy. Decreases in base exchange capacity were found to correspond closely with decreases in organic matter.
7. Losses in nitrogen were found in all cases. The average loss for the eight cultivated soils was found to be 29 per cent of the original nitrogen content. The $\frac{\textbf{organic matter}}{\textbf{nitrogen}}$ ratio was found to be decreased by cultivation, indicating a higher concentration of nitrogen in the organic matter of cultivated soils.
8. The phosphorous content of three soils was increased through cultivation. Decreases resulted in all other cultivated soils studied. In general, the eastern South Dakota soils decreased in phosphorus content as the result of cultivation.
9. The pH of western South Dakota soils was increased, while that of eastern South Dakota soils was decreased, as the result of cultivation.
10. Fig. 8 summarizes the chemical changes of South Dakota soils brought about by cultivation.

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