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The Effect of Cultivation on Erodibility of Soils by Wind[1]

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ABSTRACT

Physical and chemical analyses of the soil samples chosen at random from over 90 fields from western Kansas during 1949 and 1950 were made to determine the rates of soil deterioration that are associated with the type of agriculture employed since the breaking of the virgin sod.

In land that has been utilized for grain production for 19 years about 9 inches of topsoil, constituting all of the A horizon, has been removed, mainly by wind erosion. This land is now much less productive and contains substantially less organic matter and less undecomposed crop residues than the newly broken land. Due to lower amounts of crop residue this "old" cultivated land is more exposed to erosion by wind and water. The soil itself, however, is more resistant to erosion now than when it was first brought under cultivation, due to the presence at the surface of the finer textured and more structurally developed soil of the original B horizon. When the protective influence of crop residues was discounted, the old cultivated land was found to be less than half as erodible as land broken out of virgin sod between 1946 and 1948. With crop failures such as occur on all types of land in dry years, the recently broken land would apparently become most vulnerable to erosion by wind.

A STUDY was made of the soils of Greeley County, Kans. to determine the effects of the past land use practices on their physical and chemical properties and on their erodibility by wind. It was anticipated that the research would be an aid in planning the type of land use required to maintain the natural productivity of these soils. The soils are developed from loess. They are medium-depth silt loams with a finer textured, friable subsoil. They belong to the Baca and Ulysses series. At present, they are indicated on Kansas Reconnaissance Conservation Survey maps by the symbols 54A2 (Lo), 36A2 (Lo), and 54–36A2 (Lo). They are the predominant soil types of the semiarid, more or less level region of western Kansas and southeastern Colorado.

Prior to World War II approximately 60% of these lands in Greeley County were in native sod. Progressive breaking out of this sod started in 1942 and became virtually completed in 1950. A rather unique opportunity, therefore, existed to determine possible rates of soil deterioration and erodibility associated with the time they have been broken from sod.

These lands are known to present a potential erosion hazard when cropped to wheat. During the past years of abundant rainfall they have produced phenomenally high yields. With a return to average or below average rainfall the probabilities are that they will present a serious erosion problem. Appreciable drifting of soil by wind has occurred on them in the fall of 1948 and in the spring of 1949 and 1950. The pertinent question is whether they may be safely cropped, and, if so, for how long a period before they should be returned to grasses or other less depleting crops.

Procedure

Three groups of fields were selected in each of the 2 years that study was conducted: (a) fields broken from sod between 1946 and 1948, (b) fields broken from sod between 1939 and 1944, and (c) fields broken before 1936. Four fields from each group were selected in 1949. The same fields and at least 26 more from each group were sampled in 1950.

All fields were selected to provide as uniform slope and soil conditions as possible from an area about 15 miles square. This permitted three comparisons of the effects of the contrasting crop histories under study. The general history of each field was obtained from soil erosion survey data available at the Soil Conservation District office at Garden City, Kans. More specific tillage and cropping histories for each year subsequent to 1943 were obtained from records of the Production and Marketing Administration office at Tribune, Kans.

A 60-pound composite sample of the surface inch of soil was taken from several locations in each field. A set of undisturbed soil cores was taken also for pore space and water-holding capacity determinations. The samples were taken under dry field conditions in order to minimize breakdown of soil structure. They were collected in one field trip each year and hauled by truck to Manhattan, Kans., where the analyses were conducted. At the time of sampling, a thorough examination was made of the soil profile in each field. Records were made, where possible, of the depth of the A horizon (topsoil), the depth to the lime layer, the tillage and cropping program during the current and preceding years, and the degree of wind erosion occurring up to the time of sampling.

The laboratory analyses consisted of the following determinations:

(a) The total organic matter, determined by the modified Walkley titration method (5).
(b) The amount of crop residue, determined by washing the soil through a 1.19-mm sieve and weighing the organic residue after it was separated from the rest of the soil debris on the sieve by floating off with carbon tetrachloride and drying.
(c) The mechanical analysis, by the Bouyoucos hydrometer method (1).
(d) The water-stable aggregate analysis, by the method of Yoder (6), modified in accordance with the latest SCS recommendations.
(e) The dry aggregate structure, by the method of Chepil and Bisal (3).
(f) Erodibility in a wind tunnel, by exposing a thoroughly air-dry soil to a 25-m.p.h. wind at a 6-inch height. A 20-pound sample was placed in a trough 5 feet long, 8 inches wide, 2 inches high, and exposed to the wind for a period required for soil removal to cease.
(g) Computation of erodibility based on the dry aggregate structure (2).

Analyses were made on some soils to determine the amounts of calcium carbonate,[3] total nitrogen obtained by the usual Kjeldahl method, volume weight,[4] and percent soil pores drained at various tensions (4). Analyses were conducted at least in duplicate.

Statistical analyses by the variance method, in which variability was ascribed to differences between times of breaking sod, were made. The differences required for significance at a 1 and a 5% level were computed in order to facilitate interpretation of the results.

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[3]U. S. Regional Salinity Laboratory Method 8-b, described on p. 93 in "Diagnosis and improvement of saline and alkali soils." 1947.

[4]Weight of oven dry soil core divided by the volume of core.

Results

A study of the various fields showed that the old cultivated land, that is, land broken prior to 1936, had little or no topsoil left on the surface. In the old fields the zone of lime accumulation was, on the average, 10 inches below the surface, in fields broken between 1939 and 1945 it was 18 inches below the surface, and in fields broken since 1946 it was 19 inches below the surface. Assuming that no net removal or accumulation has occurred on the newly broken land, the data showed that from 8 to 9 inches of soil have been removed from the older cultivated land since it was placed in cultivation. This is a startling rate of removal in relation to the relatively short agricultural history of the land — a history of approximately two decades.

A summary of the results of most of the physical and chemical determinations is given in table 1. The differences necessary for significance at the 1 and 5% levels are also given in table 1. The differences between old and newly broken fields are not statistically significant in several items for 1949. Excepting nitrogen, these differences are all significant at the 1% level for 1950 when a greater number of fields were included in the study.

In old cultivated fields the B horizon now constitutes the surface soil. This soil is finer in texture than the original surface soil and contains substantially more clay and less silt and sand (table 1).

The old cultivated land now contains substantially less organic matter than the new. The old, intermediate, and newly broken land contained, on the average, 1.82, 2.30, and 2.26% organic matter in 1949, and 2.13, 2.49, and 2.53%, respectively, in 1950.

The percent of total pore space determined on undisturbed samples appeared to be about the same in the surface and subsurface soils of old, intermediate, and newly broken land. The average percent of pore spaces in the three groups of soils to a 6-inch depth was 58.1, 55.8, and 57.7, respectively, in 1949. The water-holding capacity of the undisturbed surface and subsurface soils at various tensions was likewise about the same in each of the three groups.

The carbonates, calculated as a percent of calcium carbonate, did not vary significantly among the three groups of fields. Though there has been considerable removal of topsoil from the old cultivated land, the zone of lime accumulations has not yet been exposed to the surface. The old, intermediate, and newly broken land contained within one inch from the surface, on the average, 1.31, 1.01, and 1.02% of calcium carbonate, respectively, in 1949.

In 1949 and 1950 the amount of undecomposed organic residue was much lower in old cultivated land than in other groups, but the difference was less marked in 1950 than 1949. Thus, the organic residue content in 1949 was 0.35, 0.61, and 1.11%, and in 1950 it was 0.67, 0.89, and 1.13% for old, intermediate, and new land. The productivity of the "old" land apparently has dropped considerably in this short period of agricultural use. This is reflected in lower amounts of crop residue and consequently in greater exposure of the soil to erosion by wind and water. The amount of organic residue derived from native grass in newly broken land was observed to be very small compared to the amount of crop residue. Most of the grass roots evidently decomposed within a year or two after breaking from sod.

The structure of the surface soil on old land has changed somewhat, but fortunately for the better from the standpoint of stability to wind. The amount of dry erodible soil fractions (less than 0.42 mm in diameter) is now least for the old land and greatest for the newly broken land. This is due to the removal of the coarser textured and less structurally developed A horizon and the exposure of the finer textured and more structurally developed B horizon.

Conversely, the amount of coarse water-stable aggregates (greater than 0.5 mm in diameter) is now greatest in old cultivated land and least in newly cultivated land (table 1).

Table 1.—Physical and chemical properties of soils at various periods after breaking of virgin sod in Greeley County, Kans.

Number of fields	Years after breaking	Clay <0.002 mm	Total organic matter	Nitrogen	Organic residue >1.19 mm	Dry fractions <0.42 mm	Water-stable fractions >0.5 mm	Amount eroded in wind tunnel	Computed erodibility*
	average	%	%	%	%	%	%	tons/acre	tons/acre
(As of March 21, 1949)									
4	18	18.8	1.82	0.135	0.35	43.4	13.8	1.35	2.38
4	5	15.2	2.30	0.154	0.61	42.4	10.9	1.81	1.72
4	1½	14.2	2.26	0.147	1.11	51.0	9.9	1.70	3.72
Level of significance		Differences necessary for significance at indicated levels							
1%		5.7	0.57	0.026	0.35	13.8	11.8	2.01	1.22
5%		3.8	0.37	0.017	0.26	9.2	7.8	1.33	0.90
(As of April 4, 1950)									
30	19	21.0	2.13	0.120	0.67	31.7	12.9	0.40	1.09
31	6	18.0	2.49	0.129	0.89	36.2	11.6	0.46	1.47
31	2½	17.0	2.53	0.129	1.13	40.3	10.3	0.64	2.38
Level of significance		Differences necessary for significance at indicated levels							
1%		2.3	0.37	0.013	0.24	4.8	2.4	0.25	0.79
5%		1.7	0.28	0.010	0.21	3.6	1.8	0.19	0.60

*Based on the dry aggregate soil structure; effect of organic residue disregarded.

Although the old cultivated land has a soil structure that is more resistant to wind erosion, it has less crop residue to protect it from the wind. In the spring of 1949 the differences in erodibility between the old and the new land, as measured in the wind tunnel, were not significant. The effect of lower amounts of crop residue in old land almost counterbalanced the effect of a more erodible soil structure in the new land. In the spring of 1950, however, there was more crop residue in the old cultivated land and about the same in the new land. Consequently, the old cultivated land was significantly less erosive than the new. The intermediately broken land had an erodibility between the two.

If the effect of crop residues were discounted, the differences in erodibility between the old and the newly broken land would be even greater. When erodibility was computed on the basis of clod structure alone, old cultivated land in 1950 proved to be, on the average, less than half as erodible as newly broken land (table 1). The actual degree of erosion appears to be due mainly to two opposing factors: (1) the amount of erodible fractions in the soil and (2) the amount of crop residues. With crop failures, such as occur on all types of land in dry years, the newly broken land would apparently become exceedingly vulnerable to erosion by wind. The intermediately broken land would also be more erodible than the old.

Discussion and Conclusions

Several important conclusions may be drawn from this study. First, a highly soil-depleting system of agriculture is employed on these semiarid, loessal soils at the present time. Under the present system 9 inches of topsoil, on the average, have been lost within the last 20 years. Soil depletion such as this has been generally recognized on cultivated land. This study merely confirms the general observation and establishes the rate of depletion in an area typical of one of the major areas in the Great Plains region.

The apparently more important finding based on this study pertains to the physical nature of newly broken dryland soil. This study shows, contrary to general opinion, that the newly broken dryland soils are potentially highly susceptible to erosion by wind. The binding action of native grass roots apparently lasts only a short time after breaking. The newly broken lands are highly productive. Consequently, their stability after breaking may be maintained by large quantities of organic residues that are available in good years. In dry years, however, when crops fail, the newly broken land would apparently become even more vulnerable to wind erosion than the old cultivated land.

Under existing cultural methods productivity and organic residues appear to decline sharply a short time after breaking. After a few years of cropping, therefore, the net result is high vulnerability of soil to erosion by wind. The greatest damage from wind erosion under the existing agricultural system is likely to occur within a few years after breaking of the virgin sod.

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