Reprinted from SOIL SCIENCE
Vol. 69, No. 2, February, 1950

PROPERTIES OF SOIL WHICH INFLUENCE WIND EROSION: I. THE GOVERNING PRINCIPLE OF SURFACE ROUGHNESS[1]

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Received for Publication August, 8, 1949

Erosion of the soil by wind is influenced by numerous factors. Many useful methods of wind-erosion control have been devised through recognition of the importance of these factors in field experiments. Though such experiments have markedly increased our knowledge on how to hold the soil, they have not contributed appreciably to our knowledge of what constitutes an erodible or a nonerodible soil or of why some soils are more susceptible to erosion than others. Differences in erodibility suggest that inherent soil properties and properties brought about by cultivation and accelerated erosion play an important role.

To obtain more specific answers to these problems a series of experiments was undertaken. The first of the studies was conducted to gain more adequate information on the generally recognized but little understood relationship between erodibility of soils and their physical structure. A part of the results of these studies is herein reported. Another group of experiments was undertaken to evaluate the effects of various physical and chemical factors on the erodibility by wind.

SCOPE OF THE PROBLEM

Wind erosion is dependent directly on the physical condition of the soil. Only soils in a dry state are moved by wind; neither wet nor damp soils are affected appreciably. The structure of a soil in an air-dry state is, therefore, a more reliable index of erodibility than its structure in a wet state. The water-stable structure relates to erodibility; yet it is but one of many factors that determine the dry clod structure and erodibility (4).

Changes in dry clod structure which consequently affect the resistance of the soil to wind action are brought about by various field practices and environmental conditions. The more important of these are climatic and weather conditions (8), type of tillage and seeding implements employed (5, 12), soil moisture conditions at the time of tillage (14), and kinds of crops grown (10). Several attempts have been made to determine the erodibility of soils from the dry aggregate soil structure produced by various tillage and cropping treatments in

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[1] Contribution No. 410 from the department of agronomy, Kansas Agricultural Experiment Station, Manhattan, Kansas, and the Soil Conservation Service, U. S. Department of Agriculture. Cooperative investigations on the mechanics of wind erosion.

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the field (3, 13). A few attempts have been made to measure the relative erodibility directly by subjecting the soil to an artificial wind (9, 11).[3]

The relationship between soil structure and erodibility by wind is intricate. Nevertheless, some attempts have been made to derive a formula simple enough for convenient use as a measuring stick of the erodibility of soils under various treatments in the field (3, 13). These measurements have been very useful but hardly adequate. A practical solution of the problem is needed for application in the field. Until this relationship is thoroughly understood and adequately expressed, it will be impossible to evaluate the importance of the different physical and chemical factors that affect the erodibility of the soil by wind.

The evaluation of the various factors that affect erodibility by wind falls logically into the second phase of the study. The literature reveals little study devoted to this relationship. Hardt (6) concluded from his investigations on soils in Bavaria that calcium carbonate is the chief factor responsible for erosion by wind, but that neither the size of grains nor the nature and amount of humus have any appreciable effect on erodibility. Hopkins (7) observed that soils high in calcium carbonate and in organic matter drifted badly in past years in Canada. He concluded that the fineness of soil structure is connected with the problem. Bradfield (1) affirmed that lime and organic matter do not in themselves ensure a good structure, such as is usually found in virgin soils, and concluded that much is yet to be learned concerning soil structure and the factors that affect it.

A series of investigations had been undertaken previously to find the relationship between soil structure and erodibility by wind (2, 3, 4). A graphical solution, based on experiments in a wind tunnel, was derived from these studies. This solution expressed the relationship between clod structure and erodibility. Because of the large number of constants that were found necessary to this approach, the formulas were too complicated for extensive use as a measure of erodibility of different soils. Consequently, an attempt was made to condense these into one simplified form applicable to the average effect of the most common erosive wind velocities. Experimental tests proved that the simplified form was valid within specific limits on a variety of soils of Western Canada (3).

Some important considerations pertaining to this problem have not been included in previous studies. One of these is a basic interpretation of the relationship between clod structure and erodibility by wind. The results of this study are presented herewith.

PROCEDURE

The soil materials used in this study were dune sand composed mainly of quartz grains, an alluvial fine sandy loam, a loessal silt loam, and an alluvial clay. They were thoroughly dried, passed through a nest of sieves, and stored in air-tight containers for use as required. To derive a simpler expression of ero-

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[3] Joy, E. C. Annual report on wind erosion investigations in South Dakota. S. Dak. Agr. Exp. Sta. and U. S. Soil Conserv. Serv. [Unpublished]. 1941.

Kucinski, K. Some properties of wind blown soils of Massachusetts. [Unpublished master's thesis. Copy on file Mass. Agr. Exp. Sta., Amherst.] 1946.

dibility than was possible in previous experiments (2), the limits of size of some fractions were broadened. The number of fractions was thus reduced from six to four. These were as follows:

Fraction A—Highly erodible, <0.42 mm. in diameter.
Fraction B—Difficulty erodible, 0.42 to 0.84 mm. in diameter.
Fraction C—Nonerodible, 0.84 to 6.4 mm. in diameter.
Fraction D—Nonerodible, >6.4 mm. in diameter.

To test the erodibility of the soil materials, use was made of a closed-circuit type wind tunnel described previously (15). The tests were made under wind velocities of 18 and 25 miles per hour at a 6-inch height. These velocities are based on air with a density of 0.075 pound per cubic foot. An 18-mile-per-hour wind at a 6-inch height corresponds to a moderately erosive wind occurring commonly on the High Plains. A 25-mile-per-hour wind is infrequent, but the damage that occurs to soils on such occasions far exceeds that for lower velocities. The velocity of the wind was measured with a Pitot tube directly above the leeward end of the soil sample being tested and at various heights up to 6 inches. Velocities up to this height conformed to a definite pattern described previously for a position 48 feet downwind of the tunnel (15). The soil samples were exposed in a trough 5 feet long, 8 inches wide, and 2 inches high. The trough had open ends. It was placed in the downwind part of and parallel to the length of the test chamber. The remaining floor area of the test chamber, which was 54 feet long, 3 feet wide, and 3 feet high, was covered with nonerodible gravel 2.0 to 6.4 mm. in diameter. The gravel was smoothened or roughened as necessary to produce a surface roughness similar to that of the soil. The surface of the soil was leveled by hand in a layer 1.5 to 2.0 inches thick. Surface roughness and the thickness of the layer varied somewhat, depending on the size of the aggregates used. The trough was mounted on supports which could be raised or lowered to maintain the soil surface on the same level as that of the surrounding gravel.

The amount of soil erodible under a definite wind velocity was determined by weighing the material before exposure to the wind and after soil movement had ceased. A slight amount of dust circulated through the tunnel, but it was too fine to settle on the soil or to cause abrasion. During the course of the experiments temperature ranged from 70° to 85° F. and barometric pressure from 720 to 760 mm. of Hg. These variations do not appreciably affect the erosional force of the wind.

Measurements were also made of the average roughness of the surface before and after exposure to the wind. The roughness was measured by determining the height and the number of projections per unit area of ground.

RESULTS

In all soils containing erodible and nonerodible fractions the amount of soil removed under an erosive wind force was limited by the height and the number of nonerodible fractions that were exposed on the surface by the wind. On these soils, unaffected by encroachment of erodible material from the outside, the removal of the soil material continued until the height of the nonerodible projections and their number per unit area were increased to a degree that completely sheltered the erodible fractions from the wind. Movement then ceased (fig. 1). The time required for movement to cease ranged from about 0.5 to slightly more

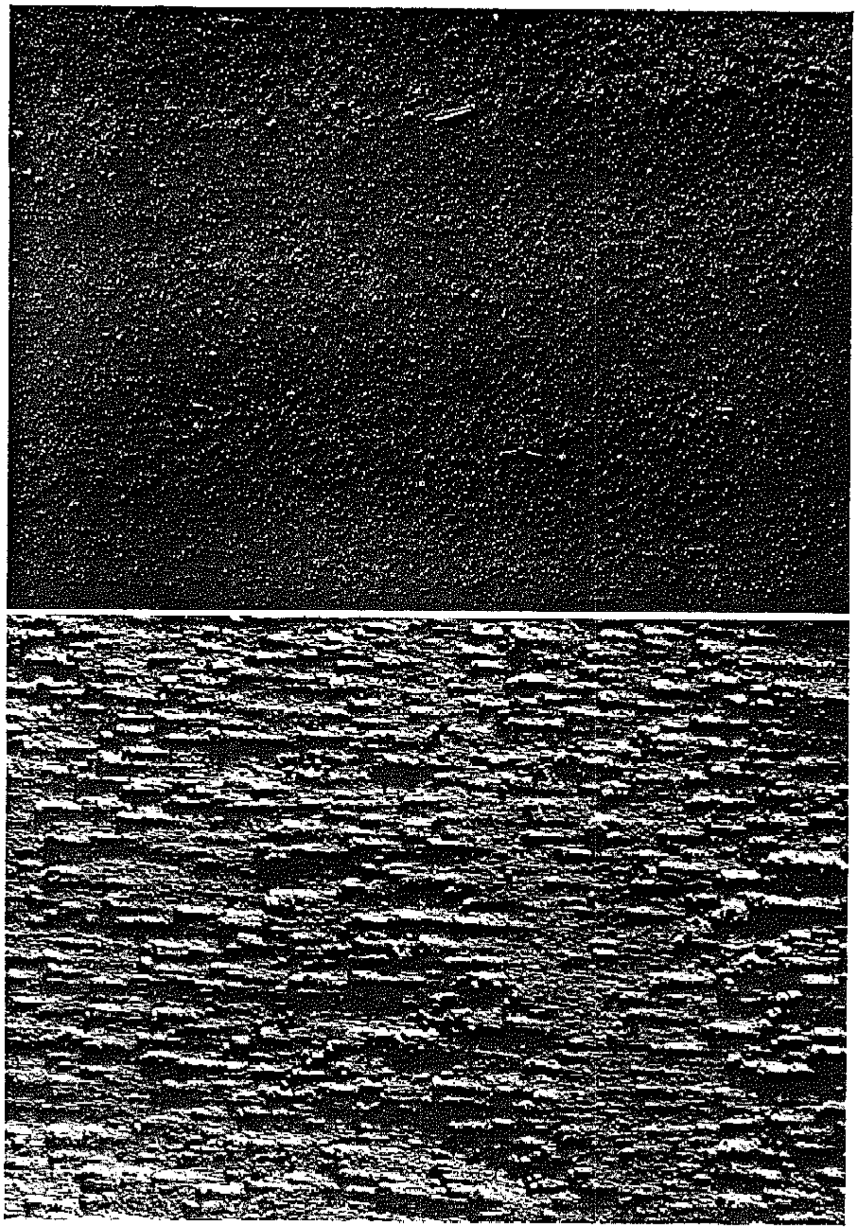

Fig. 1. Appearance of Silt Loam Soil Composed of 92 Per Cent of Fraction A and 8 Per Cent of Fraction C, (top) Before Exposure to Wind, (bottom) After Exposure Until Soil Removal Ceased

Wind velocity 18 miles per hour at a 6-inch height; wind direction left to right.

than 1 hour, depending on the structural condition of the soil (fig. 2). Two aspects of structure influenced the rate of removal: first, the smaller the size of the nonerodible clods present in the soil, the higher was the initial rate of removal and the shorter the time required for movement to cease; second, the larger the ratio of erodible to nonerodible fractions contained in the soil, the higher was the initial rate of soil removal and the longer was the time required for movement to cease.

If the soil contained a large proportion of erodible fractions, few nonerodible clods per unit area of ground became exposed by the wind. The nonerodible clods under such condition reached a very considerable height when soil removal ceased. If, on the other hand, the soil contained a small proportion of erodible fractions, large numbers of nonerodible clods were readily exposed by the wind. Removal of erodible fractions was thus restricted, and the height of the nonerodible projections reached when soil movement ceased was relatively low.

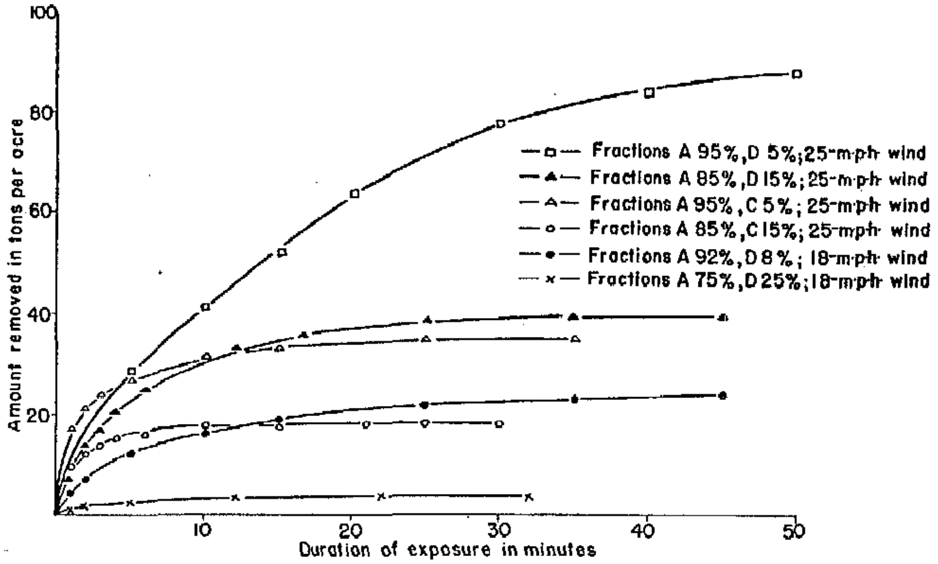

FIG. 2. RATE OF SOIL REMOVAL WITH DURATION OF EXPOSURE IN A WIND TUNNEL
Length of soil area, 5 feet.

One important principle was clearly manifested in these experiments. At a stage when soil removal ceased, the height of the nonerodible projections divided by the distance between projections[4] remained constant for any proportion of erodible to nonerodible fractions present in the soil (fig. 3). This constant may be designated the *critical surface-roughness constant*. The constant may be defined as the ratio of height of nonerodible surface projections to distance between the projections which will barely prevent the movement of erodible soil fractions by the wind. The constant varied with wind velocity and with the size and specific

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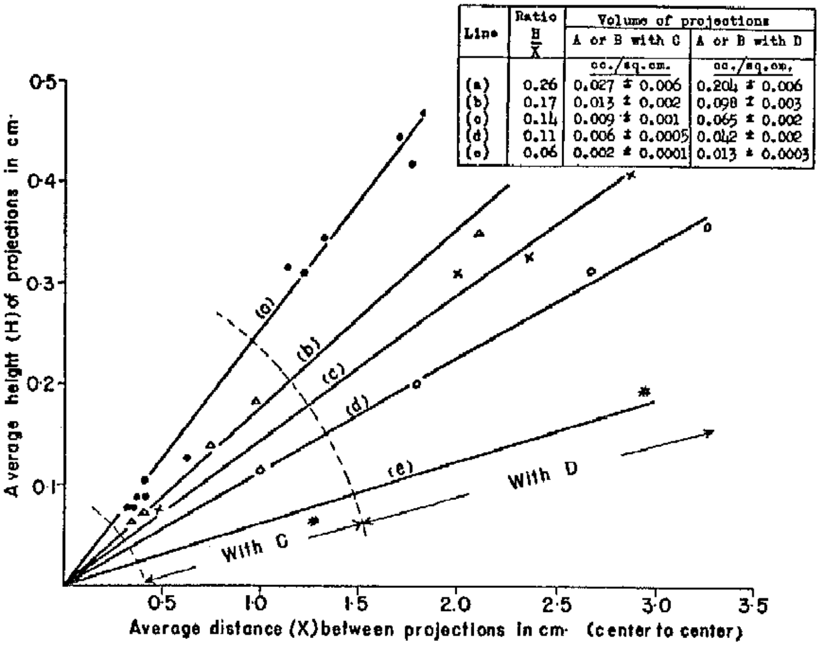
[4] Distance between projections is equal to $\sqrt{\frac{1}{N}}$ where N is the number of projections per unit area.

gravity of the erodible fractions, but remained the same for the whole range of size and proportion (by volume) of nonerodible clods.

The critical surface-roughness constant reveals the basis for the peculiar relationship that exists between erodibility by wind and the structural condition of a cultivated soil. To examine this relationship more closely, let us take as examples two samples of soil: one, a highly erodible soil containing a ratio of 9 parts erodible to 1 part nonerodible fraction; the other, a wind-resistant soil having a ratio of 1 erodible to 1 nonerodible fraction. The relative distribution of the two fractions in each soil is represented diagrammatically and to approximate scale in figure 4. In the cross-sectional diagram the nonerodible fractions are represented by rough circles, indicating approximate spheres. The level of the bed before the wind was applied is indicated by a continuous line. The erodible fractions occupy the blank spaces between the circles and below the line. The volume V of a nonerodible fraction, assumed to be a sphere, is equal to $\frac{1}{6}\pi d^3$, where d is the diameter of the fraction. The average distance from the center of one nonerodible fraction in the soil to the center of the next along a horizontal or vertical plane is represented by X. Distance X is equal to $\sqrt[3]{V(R+1)}$ where R is the ratio of erodible to nonerodible fractions contained in the soil.



Line	Ratio $\frac{H}{X}$	Volume of projections	
		A or B with C	A or B with D
		cc./sq.cm.	cc./sq.cm.
(a)	0.26	0.027 ± 0.006	0.204 ± 0.006
(b)	0.17	0.013 ± 0.002	0.098 ± 0.003
(c)	0.14	0.009 ± 0.001	0.065 ± 0.002
(d)	0.11	0.006 ± 0.0005	0.042 ± 0.002
(e)	0.06	0.002 ± 0.0001	0.013 ± 0.0003

FIG. 3. RELATION OF HEIGHT OF SURFACE PROJECTIONS TO DISTANCE BETWEEN PROJECTIONS AFTER SOIL REMOVAL BY WIND HAD CEASED

(a) Sandy loam, silt loam, and clay, fraction A with C and A with D; (b) silt loam, B with C and B with D; (c) silt loam, A with C and A with D; (d) sandy loam, B with C and B with D; (e) quartz sand, B with C and B with D. Wind velocity for (a), (b), (d), and (e) was 25 m.p.h. and for (c) 18 m.p.h. at 6-inch height.

Under a highly erosive wind velocity (25 miles per hour at 6-inch height) removal of erodible fractions continued until the surface was lowered to the dotted line in figure 4. By drawing a straight line from the peak of one projection to the new surface at the base of the next projection to leeward, the angle to the horizontal varied from 4° to 12° depending on the size and apparent specific gravity of the erodible soil fractions.

Where the diameter of the nonerodible fractions was smaller than the height of the projections required to shelter the erodible bed, the descending grains struck the erodible bed and caused a rapid removal of the erodible particles. Under such conditions the nonerodible fractions (mainly fraction C) were undermined by removal of erodible particles from below them and slid to a lower level. This process continued until a sufficient number of nonerodible fractions were exposed by the wind to stop removal of the soil. The depth of the erodible layer was thus limited by the critical height and frequency of the nonerodible fractions that were exposed at the surface by the wind.

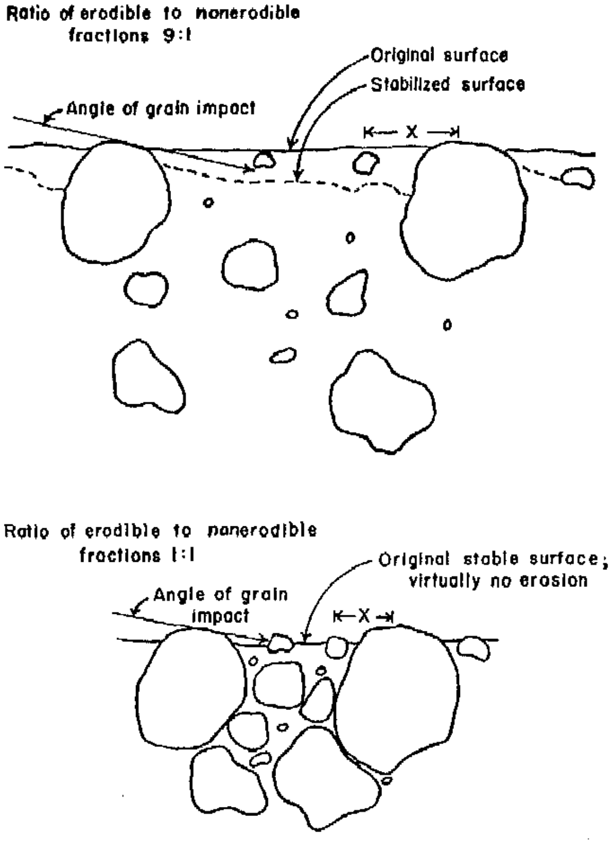


FIG. 4. DIAGRAMMATIC REPRESENTATION OF AMOUNTS OF EROSION WITH TWO DIFFERENT PROPORTIONS OF ERODIBLE TO NONERODIBLE FRACTIONS

Cross-sectional view through the maximum diameter of the nonerodible fractions.

Observations of the surface conditions produced by wind on various soils

TABLE 1

*Relation of amount of erosion to height, number, and volume of projections existing at the surface before and after exposure of soils to wind**

	25-MILE-PER-HOUR WIND AT 6-INCH HEIGHT																					18-MILE-PER-HOUR WIND AT 6-INCH HEIGHT			
	Fractions A and C						Fractions A and D				Fractions B and C				Fractions B and D	Fractions B and C	Fractions B and D			Quartz sand for B, clay for C	Quartz sand for B, clay for D	Fractions A and C	Fractions A and D		
a. Soil texture..............	Silt loam	Sandy loam	Silt loam	Silt loam	Silt loam	Sandy loam	Sandy loam	Clay	Silt loam	Clay	Silt loam	Silt loam	Silt loam	Silt loam	Silt loam	Silt loam	Sandy loam	Sandy loam	Sandy loam			Silt loam	Silt loam	Silt loam	Silt loam
b. Ratio of erodible to nonerodible fractions.........	95:5	90:10	85:15	75:25	60:40	50:50	92:8	85:15	75:25	60:40	90:10	75:25	65:35	60:40	90:10	92:8	90:10	75:25	60:40	95:5	95:5	92:8	92:8	85:15	75:25
c. Average height of projections before exposure *cm.*	0.010	0.040	0.044	0.063	0.076	0.079	0.159	0.144	0.201	0.332	0.016	0.064	0.067	0.067	0.198	0.01	0.139	0.168	0.220	0.01	0.164	0.01	0.168	0.218	0.310
e. Number of projections before exposure..*number/sq.cm.*	0.768	1.08	1.55	1.86	3.88	6.05	0.058	0.071	0.094	0.349	0.775	1.24	4.34	5.42	0.050	0.74	0.052	0.162	0.271	0.776	0.097	0.776	0.060	0.058	0.138
f. Average height of projections after exposure, *cm.*	0.106	0.125	0.088	0.087	0.079	0.079	0.469	0.419	0.445	0.310	0.181	0.139	0.070	0.071	0.352	0.118	0.361	0.312	0.203	0.059	0.194	0.073	0.410	0.326	0.313
g. Number of projections after exposure....*number/sq.cm.*	5.43	2.48	6.66	6.20	9.14	8.67	0.310	0.322	0.341	0.633	1.08	1.86	6.82	6.98	0.207	1.02	0.097	0.142	0.310	0.620	0.116	4.65	0.122	0.181	0.255
h. Volume of projections before exposure $(1/3\ \pi\ c^2(3r - c)e$ *cc./sq.cm.*	tr.	0.0009	0.0016	0.0037	0.0109	0.0182	0.0049	0.0049	0.0124	0.1208	0.0001	0.0025	0.0097	0.0121	0.0064	tr.	0.0034	0.0151	0.0427	tr.	0.0086	tr.	0.0056	0.0090	0.0419
i. Volume of projections after exposure $[1/3\ \pi\ f^2$ $(3r - f)g]$ *cc./sq.cm.*	0.0277	0.0168	0.0244	0.0223	0.0275	0.0261	0.2043	0.1723	0.2040	0.1924	0.0133	0.0151	0.0164	0.0173	0.0800	0.0063	0.0393	0.0437	0.0418	0.0011	0.0143	0.0121	0.0627	0.0605	0.0789
j. Volume of nonerodible fractions exposed by erosion.. $(i - h)$*cc./sq.cm.*	0.0277	0.0159	0.0228	0.0186	0.0166	0.0079	0.1994	0.1674	0.1916	0.0716	0.0132	0.0126	0.0067	0.0052	0.0736	0.0063	0.0359	0.0286	−0.0009	0.0011	0.0057	0.0121	0.0571	0.0515	0.0370

k. Weight of nonerodible fractions exposed by erosion (1.6*j*)† *gm./sq.cm.*	0.0443	0.0254	0.0365	0.0298	0.0266	0.0126	0.3190	0.2678	0.3066	0.1146	0.0212	0.0167	0.0107	0.0083	0.1178	0.0101	0.0574	0.0458	−0.0014	0.0018	0.0091	0.0194	0.0914	0.0824	0.0592
m. Weight of erodible fractions removed by erosion(*b k K*)..*gm./sq.cm.*	0.842	0.229	0.207	0.089	0.040	0.013	2.20	0.914	0.552	0.103	0.191	0.050	0.020	0.012	0.636	0.116	0.310	0.082	−0.001	0.034	0.104	0.223	0.631	0.280	0.107
n. Weight of erodible fractions removed by erosion (44.61 *m*)..*tons/A*	37.6	10.2	9.2	4.0	1.8	0.6	98.2	40.7	24.6	4.6	8.5	2.2	0.9	0.5	28.4	5.2	13.8	3.7	−0.05	1.5	4.6	9.9	28.1	12.5	4.8
o. Weight actually eroded in test tunnel..*tons/A*	35.7	15.6	11.1	5.4	1.5	0.6	80.5	40.2	22.4	7.1	7.1	1.9	1.0	0.6	20.8	4.1	10.4	3.0	0.5	1.3	2.8	8.1	22.0	12.1	4.9

* Determination of the volume of projections is based on the assumption that the nonerodible fractions which form the projections are spherical, average radius (*r*) being 0.18 cm. for fraction C and 1.11 cm. for fraction D. Fraction C was, in fact, nearly spherical, but fraction D was very angular; hence, a shape coefficient *K*, 1.0 for fraction C and 0.6 for fraction D, is applied.

† Specific gravity of C and D = 1.6.

served as a basis for interpreting the relationship between the dry aggregate structure and erodibility. The data obtained (fig. 3) indicated that the ratio of the height of projections to the distance between them on a surface stabilized by wind was constant for any proportion and any size of the nonerodible fractions contained in the soil. The volume of the projections per unit area of ground, however, was not constant under any condition. In the great majority of cases the volume varied but little where the size of the nonerodible fractions remained the same. The extreme variation in volume occurred for mixtures of fractions A and C on loam soil. For these mixtures the maximum deviation from the average volume was 22 per cent. In most cases, however, this deviation did not exceed 5 per cent (fig. 3).

The height and number of nonerodible projections that existed on the soil surface before exposure to the wind had an important bearing on erodibility. Under uniform soil treatment, the height and number of surface projections increased with the concentration of nonerodible fractions contained in the soil. They varied also with the size of the nonerodible fractions (table 1). With relatively low concentrations of nonerodible fractions the surface was virtually devoid of any projections. Erosion by wind continued rapidly until a comparatively great depth of soil had been removed. With high concentrations of nonerodible fractions, on the other hand, the fine particles tended to sift downward among the coarser fractions, thereby forming a relatively rough surface composed predominantly of nonerodible clods. Consequently, the amount of erosion under such conditions was very small or none at all. When interpreting the effect of the height and number of surface projections on the erodibility by wind, it was necessary, therefore, to take cognizance of the volume of projections that occurred on the surface before, as well as after, exposure to the wind.

Observations on the actual surface roughness before and after exposure to the wind were recorded under different wind velocities, and these served as a basis of a mathematical interpretation of the relationship of soil structure to erodibility by wind. The volume of surface projections before exposure subtracted from the volume after the surface was stabilized by wind indicated the volume of the nonerodible fractions that was exposed by the wind. This volume multiplied by the ratio of erodible to nonerodible fractions contained in the soil indicated the volume of erodible fractions removable by wind (table 1). A comparison of these computed amounts with the actual amounts eroded in the wind tunnel showed a high degree of agreement between the two. The dominant principle which governs the erodibility of cultivated soils is evidently based on the height and number of nonerodible projections existing on the surface before exposure to the wind and on the critical surface-roughness constant of a stabilized soil. This principle can be expressed by an equation:

$$q = KRO_u \ (V_2 - V_1)$$

where q is the amount of soil erodible by wind; V_1 is the volume of the nonerodible projections existing at the surface before exposure, assuming projections are dome shaped; V_2 is the volume of such projections after soil movement has ceased; O_u is the density of the projecting units; R is the ratio of erodible to nonerodible fractions contained in the soil; and K is a coefficient the value of which depends on the actual shape of the projecting units.

V_1 varied directly with the proportion and size of the nonerodible fractions contained in the soil. V_2 varied considerably with wind velocity and with size and apparent specific gravity of erodible and nonerodible fractions (table 1). On the other hand, it varied little with the ratio of erodible to nonerodible fractions (fig. 3).

Apparent specific gravity of the highly erodible fraction A had little if any, influence on the height, number, and volume of surface projections exposed by wind [fig. 3, curve (a)]. Consequently, it had no appreciable effect on erodibility (tables 1 and 2). Apparent specific gravity of the semierodible fraction B, on the other hand, had a great influence on the number and magnitude of surface projections and on erodibility.

TABLE 2

Apparent specific gravity of various soil fractions used in wind tunnel experiments

SOIL FRACTION	DIAMETER	APPARENT SPECIFIC GRAVITY[*]			
		Quartz sand and gravel	Sandy loam	Silt loam	Clay
	mm.				
A	<0.42	2.65	2.10	1.84	1.66
B	0.42–0.84	2.65	1.72	1.48	1.56
C	0.84–6.4	2.65	1.50	1.45	1.53
D	>6.4	—	1.57	1.66	1.58

[*] Apparent specific gravity $= 2.65 \left(\frac{\text{Weight of volume of soil grains}}{\text{Weight of same volume and size of quartz sand grains}}\right)$.

Apparent specific gravity of clods >6.4 mm. was determined by liquid displamecent method after the surface was coated with hot paraffin wax.

The shape of the nonerodible surface projections apparently influenced appreciably the amount of soil moved by wind. In all soils used, fractions C were spherical or nearly so. An assumption that surface projections composed of fractions C were sectors of a sphere of a given diameter was apparently valid (table 1). This assumption did not hold for fractions D, which were definitely more angular. If the surface projections composed of D were assumed to be sectors of a sphere of a given diameter, the computed erosion values were about twice the actual values. If, on the other hand, the projections were considered pyramidal, the computed erosion values were less than half, and if they were considered cubical more than six times the actual values. The actual shape of D projections, as indicated by coefficient K, was equivalent to that approximately half way between a spherical dome and a pyramid.

DISCUSSION AND CONCLUSIONS

For soils containing erodible and nonerodible fractions there is no definite wind velocity that will perpetuate the movement of soil material. Erosion continues until the nonerodible clods project sufficiently above the surface to give protection to the erodible fractions. Movement then ceases. In small fields, such as narrow strips, under wind of constant velocity blowing from one direction at right angles to the strip, the time required for movement to cease is relatively short (approximately 30 hours for a 20-rod strip). In large fields the time required is so much longer that soil removal under an erosive wind blowing from one direction does not cease. Nevertheless, the basis which determines the relative degree of erosion from small or large fields or from samples placed under an artificial wind in a tunnel appears to be the same. This basis is the amount of soil per unit area of surface erodible under some definite wind velocity. The rate of soil removal is not at all proportional to the total weight of erodible soil.

The frictional drag of the wind on the erodible particles immediately after soil removal has ceased is barely below that required to move the particles. The soil surface at this stage is stable and will remain stable as long as there is no increase in wind velocity, no change in wind direction, no breakdown of the nonerodible fractions by the forces of weather, and no abrasion. If for any reason the height of the projections is lowered or the distance between the projections is increased, as by forces of weather, removal of the erodible fractions on the previously stable soil will be resumed and will continue until the projections have again reached a height and lateral frequency required to stabilize the soil. At the ultimate stage of erosion much of the drag of an erosive wind is absorbed by the nonerodible clods protruding above the surface of the ground. Only the residual drag, which is just barely below that required to cause the erosion, is absorbed by the erodible fractions.

The amount of soil erodible by wind of some definite velocity is thus limited by the critical height of and distance between the nonerodible fractions that are exposed at the surface by the wind. The ratio of height of projections to distance between projections is designated as the critical surface-roughness constant. Under a given wind velocity the critical surface-roughness constant remains the same for the whole range of size and proportion of the nonerodible clods. The critical surface-roughness constant required to stabilize the soil varies with other factors, however, such as wind velocity and size and apparent specific gravity of the erodible fractions. These factors, in the aggregate, add considerably to the complexity of the phenomenon.

The critical surface-roughness constant determines, in part, the volume of the nonerodible projections exposed by wind erosion and, hence, the volume of soil removable by wind. The volume of the projections required to stabilize the surface under any given wind velocity and size and apparent specific gravity of the erodible fractions remains virtually constant throughout the whole range of proportion of erodible fractions contained in the soil. Consequently the amount of erosion can be said to vary almost proportionately, other factors being equal, with the ratio of erodible to nonerodible fractions contained therein.

The critical surface-roughness constant sets a limit to the amount of soil that may be removed by wind. The degree of surface roughness existing on the surface before exposure to the wind determines, on the other hand, how much soil may be removed before the critical roughness is reached. The volume of the surface projections before exposure is a function of soil structure. The more nonerodible fractions contained in the soil, the greater will be the volume of the nonerodible projections at the surface of the ground and the less the amount of erosion that will occur.

The volume of the surface projections before exposure to the wind subtracted from the volume after the surface is stabilized by wind indicates the volume of the nonerodible fractions exposed by erosion. This volume multiplied by the ratio of erodible to nonerodible fractions contained in the soil gives the actual volume of erodible fractions removable by the wind. The erosion values thus determined are approximately the same as the amounts eroded in the wind tunnel. The determinations thus present an insight into the general principle—the principle of surface roughness—that governs the erodibility of cultivated soils. The principle of surface roughness gives the basis for the peculiar relationship which exists between soil structure and erodibility by wind. It involves the effect of three sets of factors all of which relate to the degree of surface roughness. These factors are: (*a*) the volume of surface projections determined at the outset by the size and proportion of nonerodible clods; (*b*) the ratio of erodible to nonerodible fractions contained in the soil; (*c*) the size, shape, and apparent specific gravity of erodible and nonerodible fractions. This paper gives merely an indication of the effect of these factors on surface roughness and erodibility.

SUMMARY

The amount of soil erodible by wind is limited by the critical height of and distance between the nonerodible fractions that are exposed at the surface by the wind. Erosion ceases as soon as this critical stage is reached. The ratio of height of surface projections to the distance between projections after soil removal has ceased remains constant irrespective of the size and proportion of the nonerodible clods contained in the soil. The ratio varies with other factors, however, such as wind velocity and size, shape, and apparent specific gravity of the erodible fractions. These factors, as a whole, add considerably to the complexity of the erosional phenomenon.

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