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PROPERTIES OF SOIL WHICH INFLUENCE WIND EROSION: III. EFFECT OF APPARENT DENSITY ON ERODIBILITY[1]

W. S. CHEPIL

U. S. Department of Agriculture

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In a previous investigation[2] it was observed incidentally that the apparent density of the various structural fractions common in cultivated soils has a marked influence on erodibility of the soils by wind. The investigation gave merely an indication of the relative influence of apparent density of some of the size fractions on erodibility. A further study was undertaken, therefore, to obtain detailed information on all aspects of this relationship. The results of this study are included herein.

PROCEDURE

Three widely different soils and quartz sand, gravel, and pebbles were selected for study. The apparent density of corresponding fractions in the three soils did not differ appreciably. That of the quartz fractions, however, differed substantially from that of the soils.

After thorough air-drying, the soil and quartz materials were passed through a nest of 10 or 12 sieves, depending on the object of the investigation. The various size-fractions were stored in air-tight metal containers to be used as required. Very fine fractions, smaller than 0.044 mm. in diameter, were separated further into three subdivisions by sedimentation and aliquoting, CCl_4 being used as the suspension medium.

The apparent density of the fractions smaller than 6.4 mm. in diameter was determined by the bulk density method described previously.[3] The apparent density of fractions greater than 6.4 mm. was determined by the method of Russell and Belcerek.[4]

A closed circuit type wind tunnel with a test chamber 54 feet long and 3 feet wide was used to test the erodibility of the various soil materials. The soil samples were placed in a trough 5 feet long and 8 inches wide with both ends open. The soil surface was leveled almost smooth, either by hand or with a metal roller, depending on which gave more conveniently the roughness of surface desired. The roughness of the prepared soil surface was virtually the same for all samples tested. The trough with the soil was placed on the leeward end of the test cham-

[1] Contribution No. 423, department of agronomy, Kansas Agricultural Experiment Station, Manhattan, and the Soil Conservation Service, U. S. Department of Agriculture. Cooperative investigations in the mechanics of wind erosion.

[2] Chepil, W. S. Properties of soil which influence wind erosion: II. *Soil Sci.* 69: 403–414. 1950.

[3] Chepil, W. S. Methods of estimating apparent density of discrete soil grains and aggregates. *Soil Sci.* 70: 351–362. 1950.

[4] Russell, E. W., and Belcerek, W. The determination of the volume and air space of soil clods. *Jour. Agr. Sci.* 34: 123–132. 1944.

ber parallel to the direction of the wind. The remaining floor area was covered with gravel 2.0 to 6.4 mm. in diameter. The soil and gravel surfaces were on the same level and had a similar roughness. The purpose of the gravel was to produce a uniform wind gradient over the entire soil area. Extreme wind eddying and abnormal amount of erosion, which otherwise would have occurred on the windward edge of the soil area, were thereby prevented.

Wind velocity was measured at a 2-inch or a 6-inch height, depending on the nature of the experiment. The amount of soil eroded under each velocity was determined by weighing the soil sample before and after exposure to the wind.

For soil materials containing only the erodible fractions, two types of measurement of the effect of apparent density on erodibility were made: first, the lowest velocity of wind required to initiate and to continue the movement of soil materials of various apparent densities; and second, the rate of removal of soil of different apparent densities under different wind velocities.

For soils containing mixtures of erodible and nonerodible fractions, the rate of soil removal varied appreciably with duration of exposure to the wind. Consequently, the amount of soil removed during a given period, rather than the rate of soil removal, was taken as a measure of erodibility.

RESULTS

Relationship of apparent density of erodible fractions to initiation of soil removal from beds composed of erodible fractions

The threshold drag velocity, which is the minimal drag velocity required to initiate the movement of sand grains, was asserted by Bagnold[5] to agree closely with a square root relationship. This relationship shows that the minimal drag velocity V_{*t} of any fluid required to produce a movement of solid grains resting on a level surface varies as the square root of the grain diameter and as the square root of the difference between the density of the fluid and the grain. The relationship can be expressed by the formula

$$V_{*t} = A \sqrt{\frac{\sigma - \rho}{\rho} g\, d} \tag{1}$$

in which σ is the density of the grain, ρ the density of the fluid, g the gravity constant, d the diameter of the grain in centimerers, and A a coefficient whose value for the fluid threshold in air for grains above 0.1 mm. was found to be 0.1. Since the density of air is insignificant in comparison with the density of the sand grains, it may be disregarded in this connection, and the threshold drag velocity V_{*t} can be assumed, therefore, to vary as the square root of the product of density and diameter of the grain.

This relationship was checked for soil aggregates which differ markedly from the sand grains by virtue of their porosity. The data on the left side of figure 1 show the relationship between the fluid threshold velocity at a 2-inch height and

[5] Bagnold, R. A. The Physics of Blown Sand and Desert Dunes, p. 86. William Morrow and Co., New York. 1941.

TABLE 1

*Actual diameter, equivalent diameter, and apparent density of quartz sand and pebbles and of soil aggregates used in wind tunnel studies**

DIAMETER OF GRAIN OR AGGREGATE	QUARTZ GRAINS AND PEBBLES		FINE SANDY LOAM AGGREGATES		SILT LOAM AGGREGATES		CLAY AGGREGATES	
	Average equivalent diameter	Apparent density	Average equivalent diameter	Apparent density	Average equivalent diameter	Apparent density	Average equivalent diameter	Apparent density
mm.	*mm.*		*mm.*		*mm.*		*mm.*	
<0.1	0.07	2.58	.05	2.38	.04	2.36	.04	2.12
0.1– 0.15	0.12	2.61	.11	2.31	.11	2.25	.09	1.96
0.15– 0.25	0.20	2.62	.17	2.28	.15	1.96	.14	1.85
0.25– 0.42	0.34	2.68	.28	2.19	.23	1.78	.23	1.82
0.42– 0.59	0.52	2.72	.38	1.97	.33	1.72	.34	1.76
0.59– 0.84	0.73	2.69	.50	1.84	.44	1.62	.47	1.74
0.84– 1.19	1.02	2.67	.67	1.74	.64	1.66	.64	1.67
1.19– 2.0	1.61	2.67	.93	1.54	.93	1.54	.99	1.64
2.0– 6.4	—	2.62	—	1.51	—	1.47	—	1.47
6.4–38.0	—	2.42†	—	1.69	—	1.61	—	1.61

* Equivalent diameter is equal to $\frac{\sigma d}{2.65}$, where σ is the apparent density of a discrete soil grain or aggregate of diameter d.

† Some limestone present.

TABLE 2

Size distribution and apparent density of the dry fractions contained in the sieve grade < 0.1 mm. in diameter in different soils

PARTICLE DIAMETER*	QUARTZ SAND		FINE SANDY LOAM		SILT LOAM		CLAY	
	Size distribution	Apparent density of grain (assumed)	Size distribution	Apparent density of grain	Size distribution	Apparent density of grain	Size distribution	Apparent density of grain
mm.	*per cent*		*per cent*		*per cent*		*per cent*	
0.1–0.074	72.6	2.65	9.9	2.10	9.6	2.04	14.1	1.78
0.074–0.044	21.6	2.65	32.9	2.27	28.2	2.21	32.5	2.02
0.044–0.02	4.2	2.65	38.6	†	42.7	†	39.6	†
0.02–0.01	1.2	2.65	14.7	†	13.9	†	9.8	†
0.01–0.005	0.3	2.65	2.9	†	3.8	†	2.8	†
<0.005	0.1	2.65	1.0	†	1.8	†	1.2	†

* Particle diameter >0.044 mm. was determined by sieving, and that <0.044 mm. by rate of sedimentation in CCl_4. The particles <0.044 mm., therefore, represent the equivalent, rather than the actual, diameter.

† Impossible to measure; assumed to be 2.65.

the diameter of discrete grains or aggregates obtained from soil materials of different apparent densities. The apparent density of each fraction from these soil materials is given in tables 1 and 2. The apparent density may be defined as the weight in grams per milliliter volume of a discrete soil grain or aggregate, inclusive of any air spaces within the aggregate.

It will be seen from the left side of figure 1 and from table 1 that the threshold velocity varies directly with the diameter and inversely with apparent density of the soil grains and aggregates. When the threshold velocity is plotted against the product of grain or aggregate diameter and the square root of its apparent density, the threshold velocity values for any soil or quartz sand fall close to a single line (fig. 1, right side). This shows that for a given size of erodible fraction the threshold velocity at some fixed height varies directly as the square root of the apparent density of the fraction.

When, on the other hand, the threshold velocity of figure 1 was plotted against the square root of the product of grain diameter and apparent density, the curves thus obtained for various soil materials of varying apparent densities did

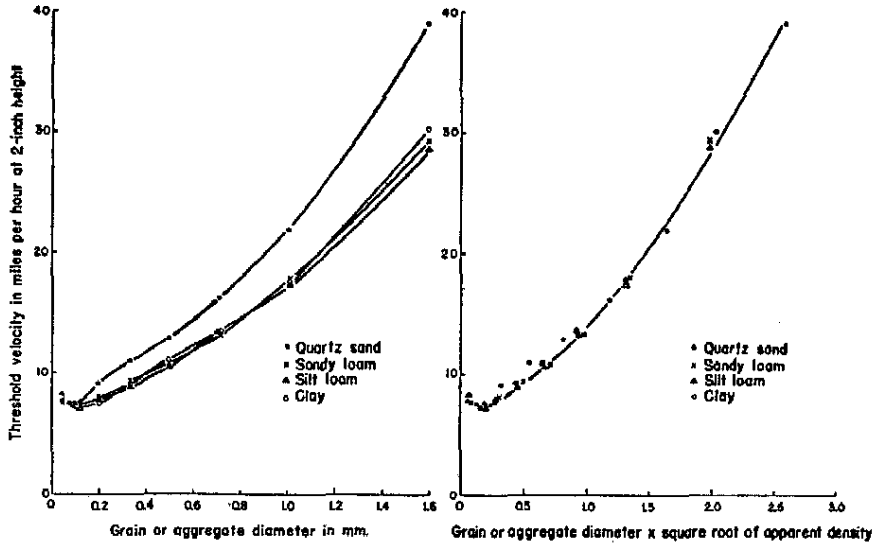

FIG. 1. RELATION BETWEEN FLUID THRESHOLD VELOCITY AND DIAMETER AND APPARENT DENSITY OF INDIVIDUAL SOIL GRAINS OR AGGREGATES

not coincide. It is evident, therefore, that the threshold velocity is influenced to some degree by surface roughness, which, in turn, is affected by the size of the erodible fraction. Bagnold recognized this and asserted that over surfaces of varying roughness the threshold velocity v_t at any height z may be determined from the formula

$$v_t = 5.75\, A \sqrt{\frac{\sigma - \rho}{\rho}\, g\, d}\, \log \frac{z}{k} \tag{2}$$

where k is a constant varying with the nature and size of the discrete fractions of which the entire eroding surface is composed. By plotting the velocity of the wind against the logarithm of height, the value of k, which is usually equal to about $\frac{1}{30}$ of the height of surface irregularity, can be estimated from a point at which the projected drag velocity curve meets the log-height ordinate. Determination of the drag velocity was considered outside the scope of this investigation. The relationship between the threshold velocity and the apparent density, however, is indicated. The data obtained (fig. 1, right side) indicate that, provided the size of the erodible fraction is constant, the threshold velocity at some fixed height varies as the square root of the apparent density of the erodible fraction. It is apparent that σ in formulas (*1*) and (*2*) as applied to soils should represent the apparent, and not the real, density of the grain or aggregate moved by wind.

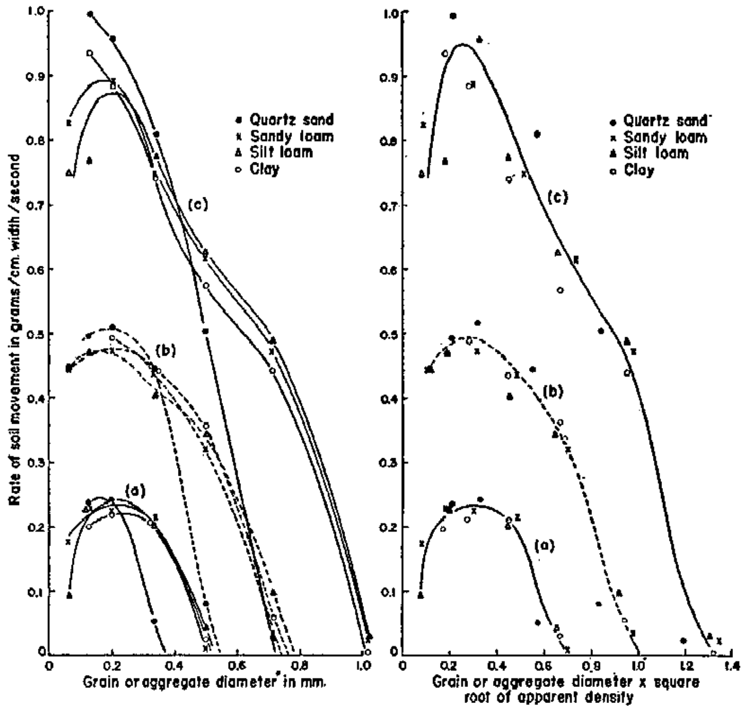

FIG. 2. RELATION BETWEEN RATE OF EROSION AND SIZE AND APPARENT DENSITY OF ERODIBLE GRAINS OR AGGREGATES

Nonerodible fractions are absent. Curves and groups of curves (a), (b), and (c) are for wind velocities of 20, 25, and 30 miles per hour at 6-inch height, respectively.

Relationship of apparent density of erodible fractions to rate of erosion of beds composed only of erodible fractions

Differences in the apparent density of erodible fractions appeared to have little or no effect on the rate of erosion of fractions up to 0.2 mm. in diameter under a 20-mile-per-hour wind, up to 0.35 mm. under a 25-mile-per-hour wind, and up to 0.45 mm. under a 30-mile-per-hour wind (fig. 2, left side). For fractions above these diameters the variation in the apparent density had a substantial influence on the rate of erosion. When the rate of erosion was plotted against the product of diameter and the square root of apparent density of the erodible fraction, the erosion values for some particular wind velocity fell close to a single curve (fig. 2, right side). It is evident, therefore, that the rate of erosion of some constant size of erodible fraction varies approximately as the square root of its apparent density, other factors being equal.

Relationship of apparent density of erodible fractions to amount of erosion from beds composed of mixtures of erodible and nonerodible fractions

Data presented in the preceding sections show the relationship between the initiation and the rate of erosion and the apparent density of any soil material composed entirely of erodible fractions. This information has little practical application in wind erosion control because cultivated soils are seldom composed of erodible fractions only. Determinations were made, therefore, to test the effect of differences in apparent density of mixtures of erodible and nonerodible fractions, such as exist in cultivated soils.

Incidental observations in a previous investigation showed that the apparent density of fraction A (sieve grade less than 0.42 mm. in diameter) had little or no effect on erodibility of cultivated soils. More detailed data obtained in the present investigation on the same soils indicate that erodibility of fraction A is affected by a peculiar combination of size distribution and apparent density of this fraction in the soils investigated. The range of size for fraction A of the previous investigation was far too great to facilitate detection of the influence of a pair of counteracting factors, one of which was apparent density and the other the size distribution of the grains. To overcome this difficulty in the present investigation, fraction A was divided by sieving into four additional size-fractions: 0.42 to 0.25, 0.25 to 0.15, 0.15 to 0.1, and less than 0.1 mm. in diameter. The erodibility of each of these fractions from each soil was determined and related to the apparent density.

Data from the present study (fig. 3) show that the apparent density of the erodible fractions greater than 0.1 mm. in diameter influences the amount of erosion appreciably. The apparent density of the component parts of the soil studied did not vary greatly. A large difference in apparent density (table 1) was between that of the soils and of quartz sand and pebbles. This difference was markedly reflected in the amount of erosion. Smaller differences in erosion occurred between soils that had relatively small differences in apparent density.

When the amount of erosion for any given wind velocity and for any given amount of nonerodible fractions was plotted against the square root of the product of diameter and apparent density of the erodible fractions greater than about 0.15 mm. in diameter, the erosion values for all soil materials with different apparent densities fell on or near a single straight line (fig. 4). The product of diameter d and apparent density σ divided by 2.65 may be termed the equivalent diameter of erodible fractions. The equivalent diameter may be defined as a diameter of an imaginary quartz grain having an apparent density of 2.65 and an erodibility equal to that of a discrete soil grain or aggregate of some particular diameter and apparent density. These results show that for mixtures of erodible fractions above 0.15 mm. in diameter and any size of nonerodible fraction the amount of erosion varies inversely as the square root of the equivalent diameter of the erodible fractions.

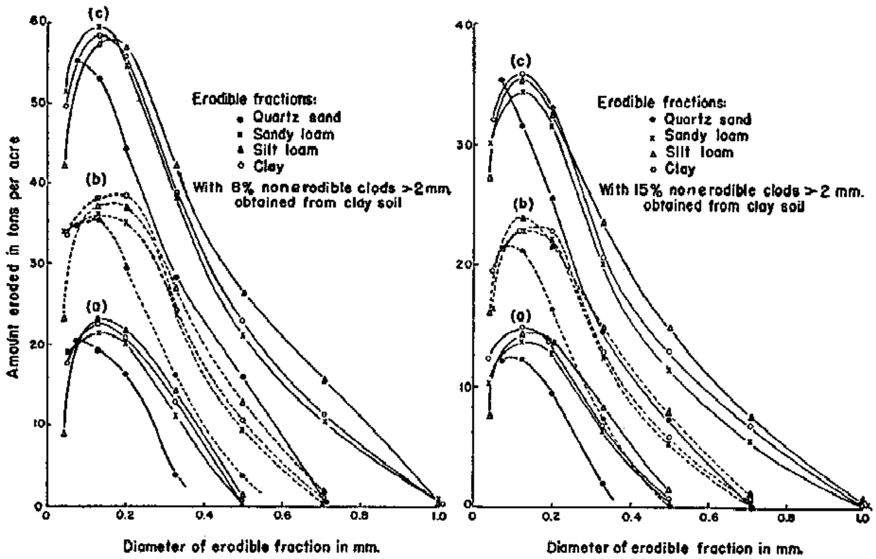

FIG. 3. RELATION BETWEEN AMOUNT OF SOIL EROSION AND DIAMETER OF ERODIBLE FRACTIONS MIXED WITH NONERODIBLE FRACTIONS

Groups of curves (a), (b), and (c) are for wind velocities of 20, 25, and 30 miles per hour respectively. Duration of exposure to wind, 10 minutes under a 20-mile-per-hour and 5 minutes each under a 25- and a 30-mile-per-hour wind.

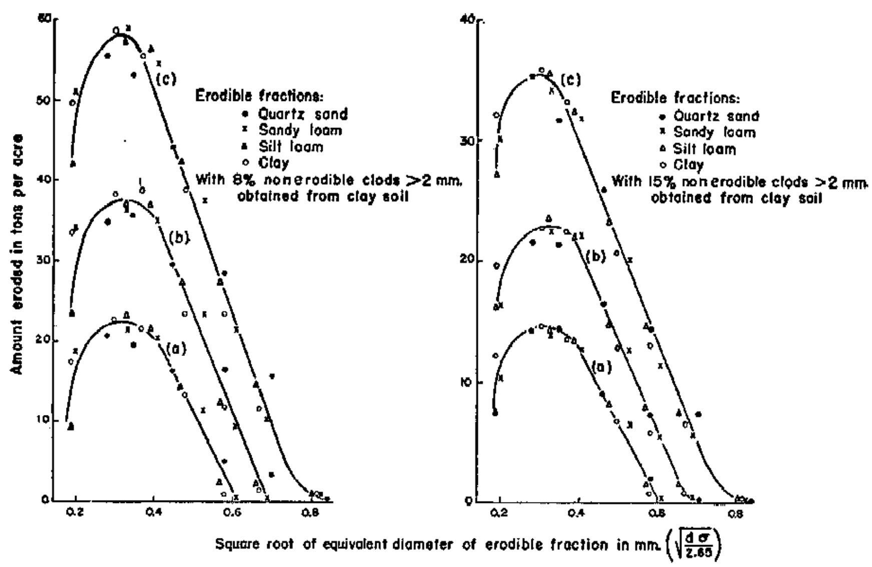

FIG. 4. RELATION BETWEEN AMOUNT OF SOIL EROSION AND EQUIVALENT DIAMETER OF ERODIBLE FRACTIONS MIXED WITH NONERODIBLE FRACTIONS

Curves (a), (b), and (c) are for wind velocities of 20, 25, and 30 miles per hour, respectively. Duration of exposure to wind, 10 minutes under a 20-mile-per-hour and 5 minutes each under a 25- and a 30-mile-per-hour wind.

The threshold velocity of beds composed only of erodible fractions as shown in the preceding section, on the contrary, did not vary as the square root of the equivalent diameter of the fraction. Lack of such relationship for beds composed only of erodible fractions apparently was due to differences in the surface roughness that were produced by differences in size of the erodible fractions. The differences in surface roughness consequently produced differences in the threshold velocity of the wind. With mixtures of erodible and nonerodible fractions (fig. 4), on the other hand, the differences in size of erodible fractions did not appear to effect the surface roughness appreciably. The dominant factor affecting surface roughness was apparently the size and amount of the nonerodible fractions. The size of the nonerodible fractions had a profound effect on surface roughness and erodibility.

For the sieve grade smaller than 0.1 mm. in diameter, the size distribution and not the apparent density was the predominant factor that governed the amount of erosion from a given wind. The silt loam fraction that passed through the 0.1-mm. sieve contained the largest quantity of dry fractions smaller than 0.02 mm. (table 2) and was, consequently, the least erodible (values on the extreme left of fig. 3). The same quartz sand grade containing the least of these fine particles was nost erodible. These differences occurred despite the fact that the apparent density of the sand grains was considerably higher than the apparent density of the soil grains (table 2). Had the apparent density of the soil grains been the same as that of the sand grains, the differences in erodibility undoubtedly would have been even greater.

To determine the effect of apparent density on erodibility of fractions smaller than 0.1 mm. it was necessary to sieve this grade into smaller subdividions. Such separation by dry-sieving to give quantities sufficient for wind tunnel tests was extremely laborious. Consequently, only two widely different soil materials, very fine alluvial sand and silt loam, were chosen. From these materials the following size fractions were obtained by sieving: 0.1 to 0.074 mm., 0.074 to 0.044 mm., and a fraction passing through a 0.044-mm. sieve. Further separation of the particles smaller than 0.044 mm. was not possible by sieving. To obtain soil material containing a still greater quantity of fine dust, part of the finest sieve grade was pulverized slightly by grinding. The size distribution of particles in the slightly pulverized grade is shown in table 3 and the erodibility of this and other fractions up to 0.15 mm. in diameter in figure 5.

The data in figure 5, like those of figure 4 for the coarser fractions, indicate that the amount of erosion varies with the equivalent diameter of the erodible fractions. The amount of erosion for particles less than 0.15 mm. in equivalent diameter does not appear, however, to conform to the square root relationship as it does for fractions greater than about 0.15 mm. in equivalent diameter. The erodible fractions 0.05 to 0.15 mm. in equivalent diameter, when mixed with nonerodible fractions such as in cultivated soils, appear to be most subject to erosion by wind. Apparently, this range of size lies in the transition zone to which no simple relationship with respect to erodibility applies. Above this range of size, the amount of erosion varies inversely as the square root of the equivalent diameter of the erodible fractions. What specific relationship is operative for erodible fractions below this range of size cannot be determined with any degree of certainty from the data available, except to say that the erodibility decreases

TABLE 3

Particle size distribution of sieve grade smaller than 0.044 mm. pulverized somewhat by grinding

PARTICLE DIAMETER	DISTRIBUTION*	
	Quartz sand	Silt loam
mm.	*per cent*	*per cent*
0.044–0.02	54.2	67.3
0.02–0.01	22.3	15.6
0.01–0.005	7.5	3.0
<0.005	16.0	14.1

* Determined by sedimentation in CCl_4.

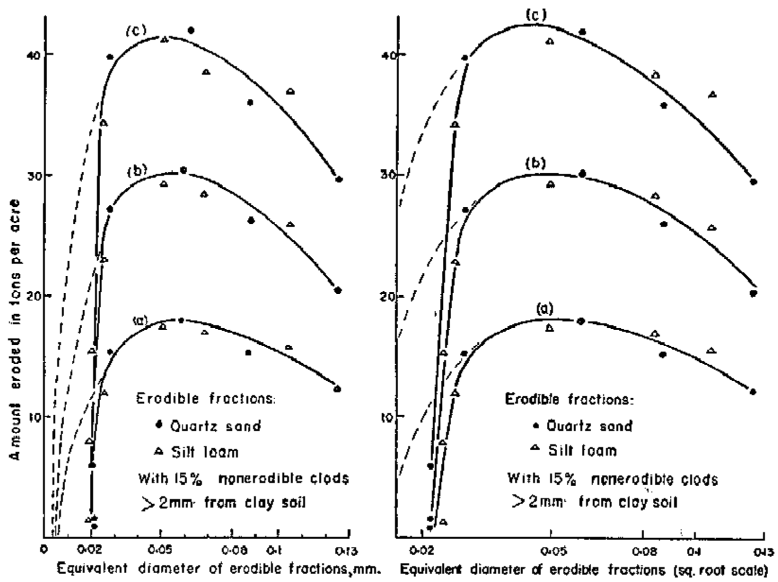

FIG. 5. RELATION BETWEEN AMOUNT OF SOIL EROSION AND EQUIVALENT DIAMETER OF ERODIBLE FRACTIONS MIXED WITH NONERODIBLE FRACTIONS

Curves (a), (b), and (c) are for wind velocities of 20, 25, and 30 miles per hour, respectively. Duration of exposure, 10 minutes under a 20-mile-per-hour wind and 5 minutes each under a 25- and 30-mile-per-hour wind.

markedly with a decrease in the size of the erodible fractions below 0.02 mm. in equivalent diameter and reaches 0 for the size approximately equal to that of Portland cement (mostly less than 0.01 mm. in equivalent diameter).

The amount of erosion appears to be governed by the equivalent diameter of each erodible fraction and not at all by the average equivalent diameter of all the fractions. For this reason, the amounts of erosion plotted against the average diameter of the last sieve grade smaller than 0.1 mm. of figures 3 and 4 and the last two sieve grades smaller than 0.044 mm. of figure 5 are misleading. In both these cases the great reduction in the amount of erosion was due to relatively small quantities of fine dust contained in mixture with coarser, much more erodible grains. Whereas fine dust of perhaps less than 0.01 mm. in diameter was the main factor which determined the amount of erosion, such fine dust contributed virtually nothing to the value of the average equivalent diameter in these sieve grades. The amount of erosion for these sieve grades, therefore, corresponds to a much lower actual equivalent diameter than is indicated. The projected curves designated by broken lines in figure 5 probably correspond more closely with the actual relationship.

Relationship of apparent density of nonerodible fractions to erodibility of soil composed of mixtures of erodible and nonerodible fractions

It was found previously[6] that the erodibility of cultivated soils is governed by the volume of the nonerodible fractions exposed on the surface by the wind. It became apparent in this study, therefore, that the weight of the soil eroded by wind is dependent on the volume, and not directly on the weight, of the nonerodible fractions originally contained in the soil. Measurements were conducted to test this hypothesis.

It was difficult to determine directly the volume of the nonerodible fractions. The volume, however, was readily computed from the weight and the apparent density of these fractions. If W_1 is the weight of the nonerodible fraction in grams and d_1 is its apparent density, then the volume of the nonerodible fraction in milliliters is equal to $\frac{W_1}{d_1}$. The volume occupied by the erodible fraction mixed with the nonerodible fraction is equal to $\frac{W_2}{d_2}$ where W_2 is the weight of the erodible fraction and d_2 is its bulk density. The bulk density may be defined as the weight in grams per milliliter volume of a bed of discrete soil fractions, inclusive of air spaces between and within these fractions. The per cent volume, V_1, of the nonerodible fractions is equal to $100\, \frac{W_1}{d_1}\left[\frac{1}{\frac{W_1}{d_1}+\frac{W_2}{d_2}}\right]$.

When the amount of erosion which occurred during a definite period of exposure to three different wind velocities was plotted against the weight of the nonerodible fractions added to the soil, curves were obtained as shown in the left half of figure 6. In this connection, different curves were obtained for different soils containing nonerodible fractions of different apparent densities. When the amount of erosion was plotted against the volume of some particular size of nonerodible fraction, the plotted values fell close to a single curve, as shown on the right half of figure 6. Slight deviations obtained on each of the two such curves

[6] Chepil, W. S. Properties of soil which influence wind erosion: I. *Soil Sci.* 69: 149–162. 1950.

probably indicate the magnitude of experimental error that was involved. The curves on the right side of figure 6 show that the amount of soil eroded varies inversely, though not proportionally, with the volume of the nonerodible fractions. The erodibility is not directly dependent on the density of the nonerodible fractions.

The experimental results confirm the hypothesis that the amount of erosion is dependent on the volume of the nonerodible fractions contained in the soil; neither the real nor the apparent density has any direct effect on erodibility except as both affect the volume of these fractions. Table 4 is presented for closer scrutiny of the data obtained.

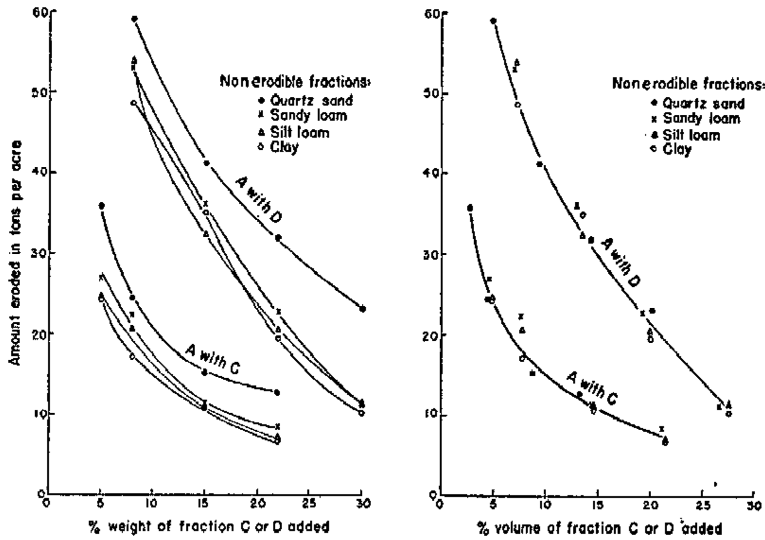

FIG. 6. EFFECT OF WEIGHT AND VOLUME OF NONERODIBLE FRACTIONS ON SOIL ERODIBILITY

Amount eroded represents the average amount removed during 10 minutes under a 20-mile-per-hour wind at 6-inch height and 5 minutes each under a 25- and a 30-mile-per-hour wind. The erodible fraction A was less than 0.42 mm. in diameter sieved out from fine sandy loam. The nonerodible fraction C ranged from 2.0 to 6.4 mm., and D from 6.4 to 38.0 mm. in diameter.

CONCLUSIONS

Erodibility is influenced substantially by the apparent density of the erodible soil fractions. Erodibility, irrespective of whether it is gauged by the threshold wind velocity at any height, by the drag velocity, by the rate of soil movement, or by the amount of soil removal during a given period, varies as the square root of the apparent density of the erodible grains or aggregates. This square root relationship appears to apply equally well to soils composed only of erodible fractions and to soils composed of a mixture of erodible and nonerodible fractions.

The apparent density of the nonerodible fractions contained in the soil has no

TABLE 4

*Effect of apparent density of nonerodible fractions on soil erodibility**

NONERODIBLE FRACTIONS					AMOUNTS ERODED			
Diameter	Texture	Apparent density	Proportion by weight added to mixture	Proportion by volume added to mixture†	Wind speed 20 miles per hour‡	Wind speed 25 miles per hour‡	Wind speed 30 miles per hour‡	Average
mm.			*per cent*	*per cent*	*tons/A.*	*tons/A.*	*tons/A.*	*tons/A.*
0.84–6.4	Clay	1.47	5.0	4.9	12.5	24.0	36.0	24.2
0.84–6.4	Silt loam	1.47	5.0	4.9	10.5	25.0	38.9	24.8
0.84–6.4	Sandy loam	1.51	5.0	4.7	12.6	26.8	41.6	27.0
0.84–6.4	Quartz gravel	2.62	5.0	2.8	18.6	35.1	53.7	35.8
0.84–6.4	Clay	1.47	8.0	7.8	8.1	16.7	26.5	17.2
0.84–6.4	Silt loam	1.47	8.0	7.8	10.0	19.8	32.4	20.7
0.84–6.4	Sandy loam	1.51	8.0	7.6	11.5	21.5	33.7	22.2
0.84–6.4	Quartz gravel	2.62	8.0	4.5	11.2	23.5	38.4	24.4
0.84–6.4	Clay	1.47	15.0	14.6	5.4	10.8	15.8	10.7
0.84–6.4	Silt loam	1.47	15.0	14.6	6.0	10.8	16.5	11.1
0.84–6.4	Sandy loam	1.51	15.0	14.3	5.9	10.9	16.9	11.2
0.84–6.4	Quartz gravel	2.62	15.0	8.8	7.6	15.1	22.8	15.2
0.84–6.4	Clay	1.47	22.0	21.5	3.4	6.5	10.4	6.8
0.84–6.4	Silt loam	1.47	22.0	21.5	3.9	7.1	10.0	7.0
0.84–6.4	Sandy loam	1.51	22.0	21.1	4.3	8.3	12.7	8.4
0.84–6.4	Quartz sand	2.62	22.0	13.3	7.7	12.6	18.2	12.8
6.4–38.0	Clay	1.61	8.0	7.2	25.3	46.5	74.3	48.7
6.4–38.0	Silt loam	1.61	8.0	7.2	29.5	52.0	80.3	53.9
6.4–38.0	Sandy loam	1.69	8.0	6.9	28.4	51.2	79.5	53.0
6.4–38.0	Quartz pebbles	2.42	8.0	4.9	31.8	56.3	89.1	59.1
6.4–38.0	Clay	1.61	15.0	13.5	19.7	34.8	50.6	35.0
6.4–38.0	Silt loam	1.61	15.0	13.5	18.1	31.5	47.5	32.4
6.4–38.0	Sandy loam	1.69	15.0	13.0	20.0	35.6	53.0	36.2
6.4–38.0	Quartz pebbles	2.42	15.0	9.4	22.3	40.1	61.5	41.3
6.4–38.0	Clay	1.61	22.0	20.0	10.0	19.5	29.4	19.6
6.4–38.0	Silt loam	1.61	22.0	20.0	10.4	21.1	30.8	20.8
6.4–38.0	Sandy loam	1.69	22.0	19.3	12.6	21.9	33.5	22.7
6.4–38.0	Quartz pebbles	2.42	22.0	14.3	18.2	31.8	45.6	31.9
6.4–38.0	Clay	1.61	30.0	27.6	4.6	10.1	16.1	10.3
6.4–38.0	Silt loam	1.61	30.0	27.6	5.8	11.1	17.7	11.5
6.4–38.0	Sandy loam	1.69	30.0	26.6	6.1	7.9	19.8	11.3
6.4–38.0	Quartz pebbles	2.42	30.0	20.2	11.2	22.0	36.2	23.1

* The erodible fraction was composed of particles smaller than 0.42 mm. in diameter sieved out from a sandy loam soil. The bulk density of the erodible fraction was 1.43.

† Percentage volume is equal to $100 \frac{W1}{d1}\left[\frac{1}{\frac{W1}{d1}+\frac{W2}{d2}}\right]$ where d_1 is the apparent density of the nonerodible fraction, d_2 is the bulk density of the erodible fraction, W_1 is the weight of the nonerodible fraction, and W_2 is the weight of the erodible fraction.

‡ Exposed for 10 minutes to a 20-mile-per-hour wind, for 5 additional minutes to a 25-mile-per-hour wind, and for 5 more minutes to a 30-mile-per-hour wind. Wind velocity was measured at a 6-inch height.

direct effect on erodibility. Erodibility is directly affected by the volume of the nonerodible fractions. Consequently, a determination of weight is meaningless unless along with weight the apparent density of the fractions is known also. The volume then could be determined by dividing the weight of the fractions by their apparent density.

SUMMARY

The following relationships were found between the erodibility of soils by wind and the apparent density of the soil fractions:

Erodibility of the soil was dependent on the volume of the dry nonerodible fractions contained in the soil. The erodibility was not directly dependent on either the real or the apparent density of the nonerodible fractions.

Erodibility of the soil, irrespective of whether it was guaged by the threshold wind velocity at some fixed height, by the drag velocity, by the rate of soil movement, or by the amount of soil removal during a given period, varied as the square root of the apparent density of the erodible grains or aggregates, other factors remaining constant. This square root relationship was found equally applicable to soils composed only of erodible fractions and to soils composed of a mixture of erodible and nonerodible fractions.

It was indicated further that under any given wind velocity and surface roughness and any given size and proportion of nonerodible fractions, the amount of erosion in cultivated soils varied inversely as the square root of the equivalent diameter of the erodible fractions. This relationship was applicable only to fractions greater than 0.15 mm. in equivalent diameter. For fractions smaller than 0.15 mm. no simple relationship such as this appeared to be applicable. The equivalent diameter is dependent, in part, on the apparent density of the erodible fractions.