Estimations of Wind Erodibility of Field Surfaces

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Three major factors influence erosion of soil by wind: surface roughness, vegetative cover, and degree of soil cloddiness. The authors indicate how these factors can be measured, how erodibility of a cultivated field surface can be determined, and what degree of surface roughness, vegetative cover, or soil cloddiness would be needed to reduce erosion to any degree. They believe that the guide presented in this paper can be used in helping the soil conservationist to determine what practices can or cannot be used to control wind erosion on different soils.

THIS PAPER PRESENTS a method to estimate relative susceptibility of field surfaces to erosion by wind or, conversely, to evaluate the effectiveness of crop residues and tillage practices in reducing erosion. The method for estimating erodibility has been developed from results obtained principally with a portable wind tunnel and accessory equipment described in previous publications (7, 8).

Three major factors appear to govern the erodibility of a land surface. These are the dry soil structure, surface roughness, and crop residue on the soil surface. All three can be measured or estimated. There are, of course, other factors—perhaps the most important are surface barriers and the size, shape, and topographic layout of a field. Also, the presence or absence of a surface crust is an important factor; however, no technique has been found to measure it successfully. Despite such limitations, results of field studies have provided the background for making approximate estimates of erodibility of field surfaces from the three major factors. These estimates are tools for a better understanding of wind erosion and for determining more conclusively how it may be controlled best.

Some of the objectives and reasons for estimating the erodibility of farm fields are: (a) to determine probabilities of wind erosion in the near future or during the next windy season so that some warning may be given in advance, (b) to determine the degree of surface roughness and/or soil cloddiness required in an emergency control program to supplement the amount of vegetative cover available on the land, and (c) to determine effectiveness of crop residues and tillage practices in providing protection against wind for different soils and physical conditions of the soils.

Determining Surface Roughness

The rougher the surface the greater is its tendency to lower the surface velocity of the wind and to reduce the movement of soil by wind. The degree of surface roughness depends on height, length, density, and quality of vegetative cover and on size, shape, and lateral frequency of clods, ripples, and ridges. It is extremely difficult to determine surface roughness by measuring these surface obstructions. For this reason a "ridge roughness equivalent" based on the height of ridges composed of fine gravel 2 to 6.4 mm. in diameter and having a height-spacing ratio of 1:4 was devised. For example, if the ridge roughness equivalent is four inches, the surface has a roughness and resists wind to the same degree as gravel ridges four inches high and 16 inches apart at right-angles to the direction of the wind.

Measuring ridge roughness equivalents without a wind tunnel is virtually impossible, but estimates can be made with reasonable accuracy from photographs of different field roughness for which the ridge roughness equivalent is known. Photographs have served as a standard guide for visual estimation of ridge roughness equivalent of field surfaces. These standard photographs are given in figure 1 with a number beside each photograph referring to ridge roughness equivalent, designated by K, in inches. The amount of crop residue, R, above the surface of the ground also is indicated as supplementary data in each case.

Figure 1.—Guide for visual estimation of ridge roughness equivalent of field surfaces with the aid of 18 photographs. The ridge roughness equivalent K is in inches. The amount of crop residue R above the surface of the ground is in pounds per acre. The photos are shown on the following six pages.

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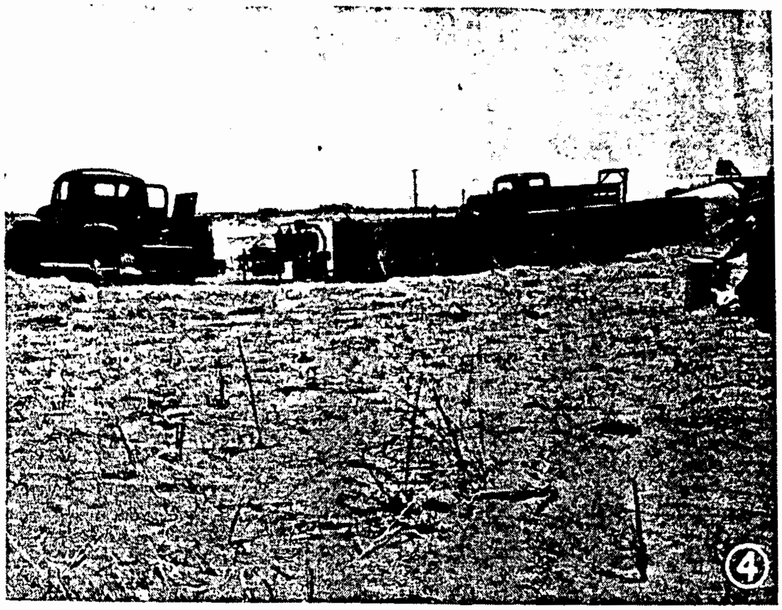
Grateful acknowledgement is made by the authors to A. W. Zingg for contributions to this study and for his part in developing and constructing a rotary hand sieve herein described.



K = 2.0 inches

Loose surface of loamy sand with some grass.

R = 311 lbs./acre

K = 2.0 inches

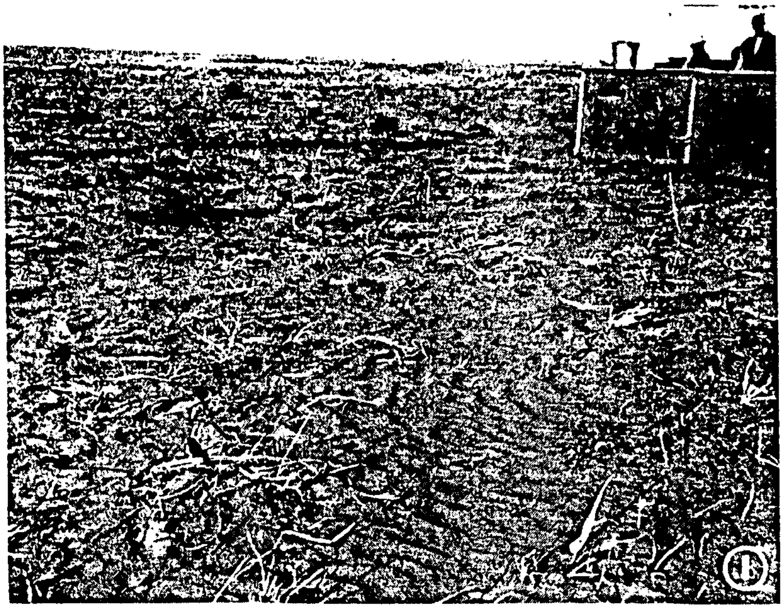
Smooth surface with very sparse sorghum stubble.

R = 400 lbs./acre

K = 2.5 inches

Smooth surface with very short, thin sorghum stubble.

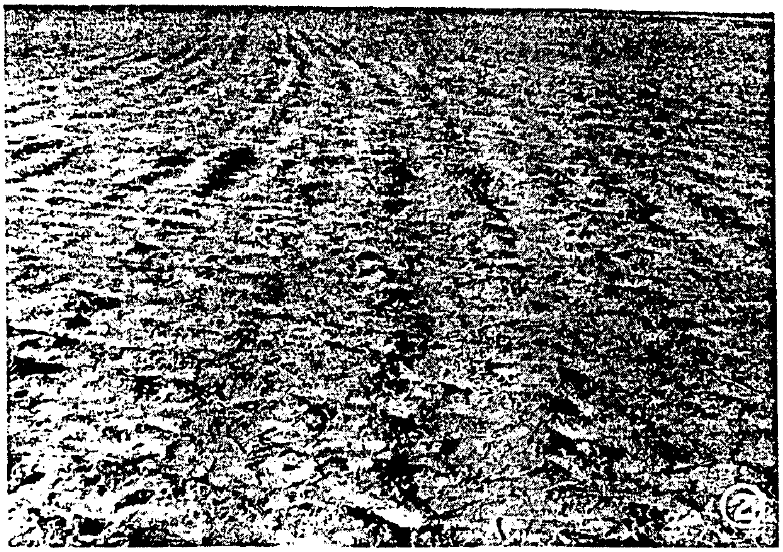
R = 245 lbs./acre



K = 1.0 inch

Loose blowing sand virtually bare and smooth.

R = 312 lbs./acre



K = 1.5 inches

Smooth fallow surface beaten down by rain, virtually bare.

R = 224 lbs./acre

K = 1.6 inches

Good wheat residue cover, flattened down with one-way disc.

R = 425 lbs./acre

K = 4.0 inches

Recently plowed land, cloddy and moderately rough surface.

R = 100 lbs./acre

K = 4.3 inches

Cotton, machine stripped.

R = 1,090 lbs./acre

K = 4.35 inches

Sorghum stubble cut with binder 5 to 7 inches high, 40-inch rows.

R = 575 lbs./acre

K = 2.6 inches

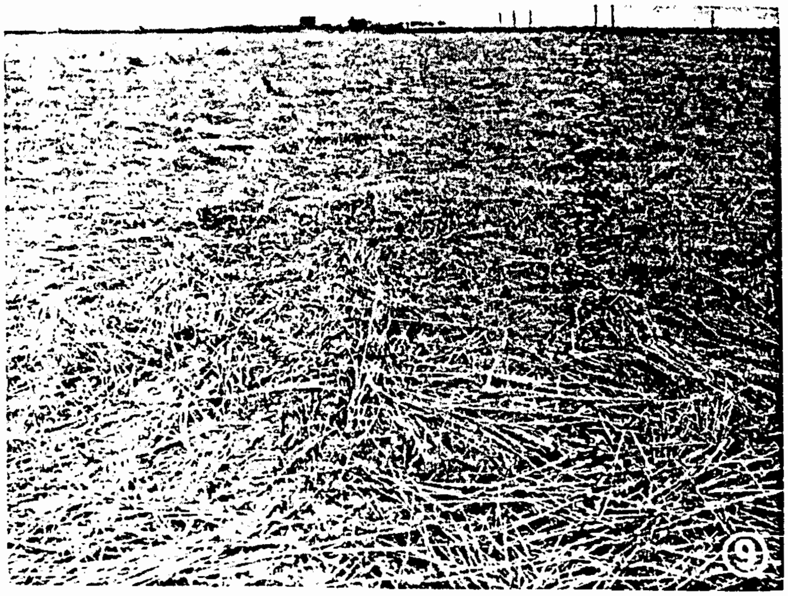
Semi-deep furrow drill ridges with some wheat stubble.

R = 790 lbs./acre

K = 3.2 inches

Good stand of growing wheat about 3.5 inches high, slightly ridged by drill.

R = 779 lbs./acre



K = 4.0 inches

Heavy combine wheat stubble partly flattened by one-way disc.

R = 3,980 lbs./acre

K = 8.5 inches

Heavy sorghum stubble (on irrigated land), thick and leafy, cut 8 to 10 inches high, 40-inch rows.

R = 1,890 lbs./acre

K = 10.1 inches

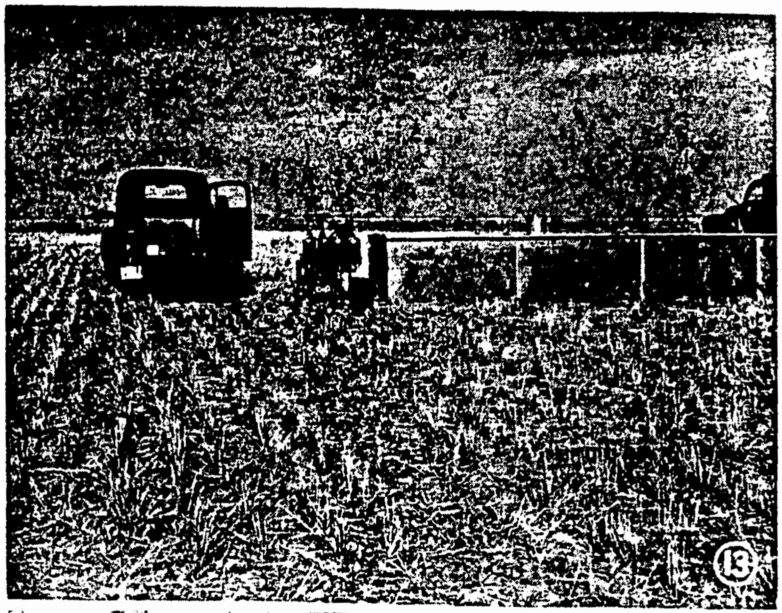
Listed, with little or no residue on top.

R = 155 lbs./acre

K = 12.5 inches

Irrigated milo combined for grain, leaving 16- to 18-inch stubble as shown on extreme right. Rest of photo is irrelevant.

R = 2,275 lbs./acre



K = 4.4 inches

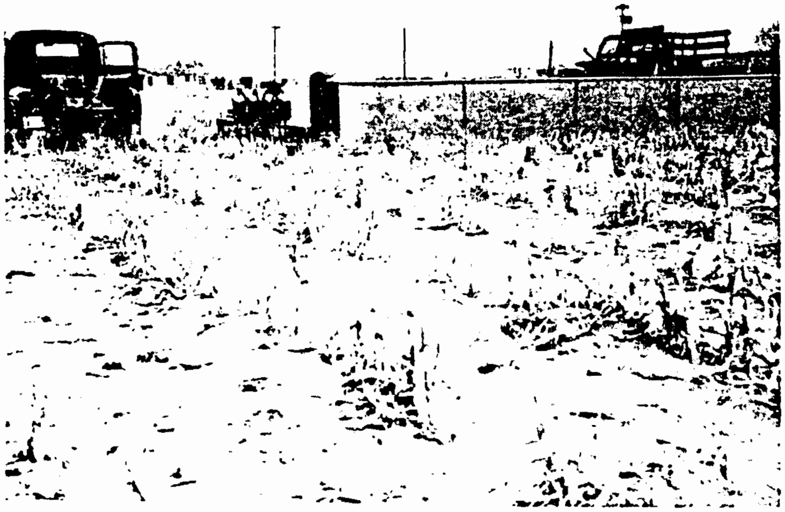
Wheat stubble combined 8 to 10 inches high.

R = 1,090 lbs./acre

K = 4.6 inches

Chiseled sorghum stubble with some large clods; considerable drifting.

R = 640 lbs./acre



K = 6.3 inches

Sorghum combined 10 to 12 inches high, 40-inch rows.

R = 1,220 lbs./acre

of residue is applied to the surface of this same field, making a total residue amount of 2,000 pounds per acre which increases the ridge roughness equivalent to 5.0 inches. The alignment chart now shows the erodibility to be 0.9 ton per acre, which is a substantial reduction from the original condition. The effectiveness of stubble and other crop residue grown on the land could be measured in the same manner.

The alignment chart may also be used to measure the effectiveness of tillage practices, such as listing or chiseling to provide protection from the wind. The procedure in this case would be to carry out the practice, determine the percentage of nonerodible fractions in the worked soil, measure the residue, estimate K, and thus determine the erodibility from the chart. If a previous estimate had been made before working, the effect of the tillage could be evaluated. For example, assume a soil with a ridge roughness equivalent of 1.0 inch, a residue amount of 200 pounds per acre, and 17 per cent nonerodible fraction. The erodibility as determined from the chart would be 25 tons per acre. Let us assume that this same soil is worked with a lister and it increases the nonerodible fraction to 52 per cent, increases the ridge roughness to 10 inches, and buries 100 pounds per acre of residue leaving only 100 pounds per acre. The chart now shows the erodibility to be 0.25 ton per acre; thus, the lister through the process of increasing the nonerodible fractions and increasing the surface roughness has reduced the erodibility from a very high amount to an insignificant amount.

Interpretation and Limitation of Estimations

A wind erosion classification based on the relative erodibility values of figure 3 may be made as follows:

Erodibility value	Erodibility	Basis of classification
< 0.25	Insignificant	Soil is sufficiently protected by clods, ridges, or vegetative cover to make it essentially nonerodible.
0.25 to 5.0	Slight to moderate	Soil is only partly protected from erosion.
> 5.0	High to very high	Soil is highly erodible and its surface is virtually unprotected from wind.

Erodibility values of figure 3 serve merely as a relative measure of wind erosion. A tunnel different from the one on which these erodibility values are based, no doubt, would produce different amounts of erosion even under apparently the same wind force. The measured amounts of erosion are based on a drag of 3,000 pounds per acre. Relative values of erodibility would change little if a different drag were used. The amount of soil eroded under the same atmospheric wind force in the field also varies, depending on dimensions of the field, geographic location, and many other factors. Consequently, the actual amounts of soil moved by wind in a tunnel or in the field have little significance unless all the conditions that influence erosion are specified.

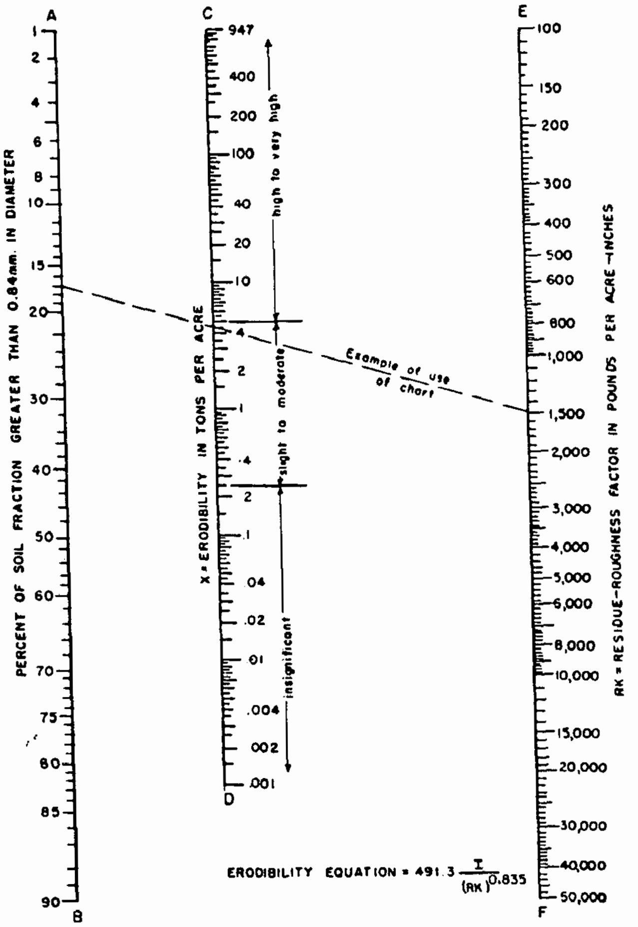


Figure 3.—Allignment chart for soil erodibility by wind.

The present estimations are based on average results obtained from tests on some 88 farm fields covering a wide range of soil textures, soil surface conditions, and residue amounts. They are applicable to fields having roughness, residue, and cloddiness falling within the limits shown on the alignment chart. These conditions can be evaluated by procedures outlined in this paper. Some field experience might be necessary for making reliable estimations of these conditions, especially where visual estimations are used.

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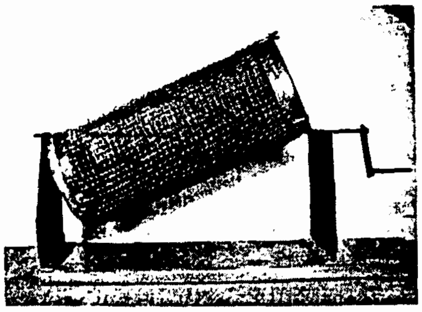

Figure 2.—Rotary hand sieve for use in the field. The cylindrical sieve is 20 inches long and 8 inches in diameter mounted eccentrically on a crank rod resting on a support base. The sieve has square openings 0.84 mm. in diameter. One-half inch metal screen is wrapped around it for support.

Determining Crop Residue

Three one-square meter samples of crop residue selected at random appear sufficient in most cases to represent an average amount over the land. The residue on or above the surface is raked or cut off level with the ground and together with whatever soil may cling to it is placed in a tray or sack and labeled. The residue is brought to the laboratory, washed thoroughly on a 1.68 mm. screen, dried in an oven, and weighed. The weights are then expressed in pounds per acre.

It is believed that, where facilities are lacking, the amounts of residue may be estimated visually in a manner similar to that used for determining the ridge roughness equivalent. Standard photographs indicating different amounts and kinds of crop residue would facilitate the estimates.

Determining Soil Cloddiness

A nonerodible soil fraction greater than 0.84 mm. in diameter, as determined by dry sieving, has been used successfully as an indicator of erodibility of soil by wind (1, 6). Although this fraction is not the only factor that influences erodibility, it is by far the most important. A technique for sampling the soil and sieving it on an automatic rotary sieve has been described previously (2, 3).

A simple hand-rotating sieve, such as that shown in figure 2, may be used conveniently in the field. The results of seiving depend somewhat on soil moisture, size of sample, speed of turning, and number of turns. These factors must remain constant if results of sieving are to remain comparable to those obtained with the automatic rotary sieve. The following conditions are adhered to when using the hand-rotating sieve:

1. The soil is sieved only when it is reasonably dry. If not dry, the soil may be brought into the laboratory, dried, and then sieved.
2. The soil to be sieved is taken down to the same depth in all comparable cases. For estimating erodibility, a layer from surface about 1 inch deep is taken.
3. Weight of sample sieved is four pounds (1,812 grams).
4. Speed of turning is two turns per five seconds. The speed can be gauged by keeping an eye on the second hand of a watch while turning.
5. The number of turns for sand, loamy sand, and sandy loam is five; for loam, silt loam, clay loam, and silty clay loam, ten; for silty clay and clay, 15.

The soil remaining in the sieve is weighed and expressed in percentage of total weight of soil.

Determining Erodibility or Conditions Required to Prevent Erosion

Field studies during the past five years to evaluate erodibility of farm fields (4, 5, 9, 10) have indicated the following average relationship:

$$X = 491.3 \frac{I}{(RK)^{0.835}}$$

where X = amount of erosion in tons per acre.
I = soil erodibility index based on percentage of surface material greater than 0.84 mm. in diameter.
R = amount of crop residue in pounds per acre.
K = ridge roughness equivalent in inches.

The alignment chart shown in figure 3 permits a convenient graphical solution of this equation and is all that is required for estimating soil erodibility from determined conditions of soil cloddiness, surface roughness, and crop residue. Values of I are replaced by corresponding percentages of nonerodible soil fractions (table 2 of reference 4). Erodibility is read from the chart as follows: A straightedge is passed through the percentage value of nonerodible fraction greater than 0.84 mm. on line AB and through the value of RK (the product of residue in pounds per acre and ridge roughness equivalent in inches) on line EF. The erodibility value corresponding to these conditions lies at the point where the straightedge crosses line CD. Thus, let it be assumed that the proportion of nonerodible soil fraction is 17 per cent and the product RK is 1,500; then erodibility read from line CD is 4.5 tons per acre. This example is shown by a dotted line in figure 3.

The alignment chart can be used similarly to determine the effect of given amounts of residue in reducing erosion. The procedure for doing this would be to determine the nonerodible fractions by sieving, measure the amount of residue already on the field, then apply a given amount of additional residue and determine the ridge-roughness K from the photographs. For example, assume a field has a soil surface containing 17 per cent nonerodible fractions, 200 pounds of residue per acre, and a ridge roughness equivalent of 2.0 inches. The alignment chart shows the erodibility to be 14 tons per acre. Now further assume that 1,800 pounds per acre

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COMPARISON OF ESTIMATED WITH NATURAL WIND ERODIBILITY OF FIELD SURFACES

During 1954 and 1955 wind erodibility was estimated from soil cloddiness, amount of residue, and roughness of surface on 55 sites representing as many fields in western Kansas and eastern Colorado. Amount of natural erosion also was determined for each site. The purpose of this study was to check the validity of estimations of wind erodibility of field surfaces according to the method described in the accompanying publication. The amount of erosion on each site was estimated early in March and again late in April. The amount of erosion was determined from the estimated average depth of soil removed from each site converted to tons per acre on the basis of 2 million pounds of soil per 6-inch depth per acre.

Soil accumulations on surfaces covered with vegetation or vegetative matter were designated as such and the amount of erosion in such cases was considered zero even if some of the accumulation was moved by wind later in the season.

The average computed erodibility and the amounts of natural erosion on 3 major groups of soil are shown in table 1. Computed erodibility was lower on sand and loamy sand, about equal on sandy loam, and higher on silt loam and silty clay loam than the natural amount of erosion at the time of computation. The spread between computed and natural erosion became even greater later in the season -- the sand and loamy sand becoming much more erodible, the sandy loam considerably more erodible, and the hardlands remaining about equally erodible. It was evident from these results that sandy soils, once "broken loose" by natural erosion, became more erodible as the season progressed, whereas the hardlands tended to become stabilized, either by increased vegetative growth or by removal of loose soil material on the surface of the ground.

Table 1.--Computed erodibility and amounts of natural erosion on three major groups of soil in 1954 and 1955.

Soil class	Computed erodibility March 15	Relative Amount of erosion	
		At time of computing	About April 30
	tons/acre	tons/acre	tons/acre
Sand and loamy sand	3.28	5.0	25.0
Sandy loam	0.89	0.89	2.72
Silt loam, silty clay loam	0.22	0.17	0.22

It is evident that one important factor influencing erodibility has not been recognized in estimations of erodibility of field surfaces. These estimations are based on results of wind tunnel tests. The wind tunnel evidently measured primarily the amount of loose soil material that was blown off under a certain wind. Due to relatively short length of tunnel, the erodible soil material was blown off the test area without causing an appreciable amount of abrasion and movement of the rest of the soil. Erosion ceased as soon as the loose material was blown off. This seldom happens in the field, especially if the soil is sandy and subject to disintegration by the cutting action of loose material. In the field, once erosion starts it usually continues and actually increases in intensity with distance across the field and with each subsequent wind. The effects of abrasion are appreciable. Loose material travels long distances and cuts into the surface crust and clods thereby creating more and more erodible material which in turn is carried by the wind. The sands are most susceptible to this cumulative abrasive action because they do not have much fine material to cement the grains together. The surface crust in sand is virtually non-existant and clods are exceedingly fragile and disintegrate readily under abrasion. Next in order of resistance to abrasion are the loamy sands, then come the sandy loams, and then the loams, silt loams, and silty clay loams. The latter group of soils, which constitute most of the "hardlands" are probably the most resistant to the abrasive action of wind erosion. Their resistanse is due to ease with which they are dispersed by water and their tendency to form a wind-resistant surface crust after they are wetted and dried. The amount of natural erosion increased over the estimated amount inversely with the fineness of soil texture.

Soil class based on texture, therefore, serves as an index of resistence of clods and surface crust to disintegration by wind erosion. Erodibility as computed from the proportion of nonerodible clods, roughness of surface, and amount of crop residue may be corrected to actual erodibility merely by multiplying the computed erodibility by an appropriate factor applicable to each soil class. The correction factors for some of the major soil groups are given in table 2. The factors are based arbitrarily on the average amounts of natural erosion occurring near the beginning and the end of the blowing seasons of 1954 and 1955. These factors mean little

Table 2.-- Correction factors for computed erodibility of major soil classes.

Soil class	Correction factor for computed erodibility
Sand and loamy sand	5
Sandy loam	2
Silt loam, silty clay loam	0.9

as absolute values. Different seasons no doubt would give different factor values depending on differences in severity of wind and other conditions. But the relative values of erodibility are expected to remain the same. Thus, if in other years the correction factors should be double in value to those for 1954 and 1955, the relative values of erodibility would still remain the same. The same applies to soils of different regions. It would not be fair to compare the amount of natural erosion of a site in one region with that in another region where climatic conditions are different, but the relative erodibility of sites having the same cloddiness, amounts of residue, roughness of surface, and soil texture within any region that has uniform climatic conditions should remain the same. The climatic conditions in western Kansas and eastern Colorado where this study was conducted were fairly uniform, though admittedly some degree of variation existed.

It is shown in this study that there are at least 4 major factors affecting wind erodibility of field surfaces and that the tunnel is capable of assessing the relative effects of the three of them. It should not be construed that the tunnel has failed in its application for measuring erodibility of field surfaces. On the contrary, the tunnel has served as an indispensible tool for this purpose.