

Conversion of Relative Field Erodibility to Annual Soil Loss by Wind¹

W. S. CHEPIL²

ABSTRACT

Relative field erodibility based on many previous wind tunnel and field measurements is merely an index of the quantity of soil loss that would occur under certain climatic conditions. This paper, based on additional measurements, shows the relationship between the relative field erodibility and the quantity of soil loss and presents a table for converting the relative field erodibility, as determined from seven major factors, to soil loss in tons per acre per annum as would occur under climatic conditions such as existed in the vicinity of Garden City, Kansas, during the years 1954 through 1956.

A TECHNIQUE to estimate relative wind erodibility of field surfaces from soil, surface, and field conditions was developed and presented in previous publications (2, 3, 5). The technique was based on information obtained principally from wind tunnel tests. Since the quantity of soil eroded in a tunnel is governed by length and other characteristics of the tunnel, erodibility was expressed on a dimensionless basis so that for a given condition of soil and surface the same relative value of erodibility would be obtained regardless of the size of tunnel within certain recognized dimensions used. This was done by expressing soil erodibility in terms of index I which is equal to X_2/X_1 in which X_1 is quantity eroded when the soil contains 60% of clods greater than 0.84 mm. and X_2 is the quantity eroded under the same set of conditions from soil containing any other proportion of clods greater than 0.84 mm. in diameter (1).

Index I multiplied by crop residue and surface roughness factors gave the relative wind tunnel erodibility (3). This erodibility multiplied by an appropriate soil textural factor F indicated the relative natural erodibility that would occur in large fields (5). The relative natural erodibility multiplied by width of field, wind barrier, and wind direction factors gave a relative measure of field erodibility (2).

It was not known what the relative field erodibility meant in terms of actual soil loss by wind. A field study undertaken in western Kansas and eastern Colorado during severe wind erosion seasons of 1954, 1955, and 1956 supplied the necessary information. This paper presents an analysis of the information and gives the quantity of soil loss in tons per acre per annum for any relative field erodibility as determined from various field conditions.

Procedure

Sixty-nine sites representing as many fields, most of which were sown to wheat during the previous fall, were chosen for this study. In no case were the dimensions of a chosen field less than 40 by 80 rods.

Quantity of soil loss on each field during the season January 1 through April was determined from estimated average depth of soil that was removed, converted to tons per acre on the basis of 2 million pounds of soil per 6-inch depth per acre. Soil accumulation on surfaces covered with vegetation or vege-

tative matter was designated as such and the quantity of erosion in such cases was considered zero even if some of the accumulation was moved by wind later in the season. The average depth of soil removal was usually indicated by the depth to which wheat crowns and roots were exposed. Then too, the depth of removal was gauged by differences occurring between the beginning and the end of the season in the depth to the tillage pan. In one case the soil was removed almost to the depth of tillage and in another, below the depth of tillage.

It was impossible to measure depths of removal much less than $\frac{1}{2}$ inch. In such cases of relatively small quantities of soil removal, two categories of erosion were recorded. One category included no visible soil erosion and no injury to winter wheat; the other included visible erosion and soil removal but not sufficient to kill winter wheat in boot stage. The third category included removal to a maximum depth of $\frac{1}{2}$ inch (assumed mean depth of $\frac{3}{8}$ inch) in which wheat was completely destroyed. The fourth category included removal from $\frac{1}{2}$ to 1 inch (mean depth of $\frac{3}{4}$ inch); the fifth from 1 to 2 inches (mean of 1.5 inches); and the sixth included the actual measured depth 2 inches or more.

Annual soil loss from each field was based on wind erosion conditions as existed during the soil drifting season from January 1 through April in the vicinity of Garden City, Kansas, during 1954 through 1956. The annual soil losses were estimated from seasonal soil losses on the basis of number and intensity of dust storms recorded at Garden City Agricultural Experiment Station during 1954 through 1956. On the average, 77.5% of wind erosion, as indicated by number and intensity of dust storms in any calendar year, occurred during the season January 1 through April. Table 1 indicates the number and intensity of dust storms at that location during those years and the manner of estimating the annual from seasonal soil loss on the basis of number and intensity of dust storms. The intensity of dust storms was measured in terms of quantity of dust at 6 feet above ground as determined from visibility—dust concentration relationship given in a previous publication (4). On the basis of this information, the factor for converting seasonal to annual soil loss was taken as 1.293.

The relative field erodibility for each field was determined from soil cloddiness, quantity of crop residue above the surface of the ground, surface roughness, soil texture, size of field, presence of wind barriers, if any, and prevailing wind direction with respect to the field according to the procedure outlined in previous publications (2, 3, 5).

Relationship Between Soil Loss and Relative Field Erodibility

Table 2 includes basic data on the relation between annual soil loss and relative field erodibility together with information on the effects of erosion on winter wheat. It will be noted that the soil loss as determined from meas-

Table 1—Estimation of annual from seasonal soil loss on the basis of number and intensity of dust storms at Garden City, Kansas, during 1954-56.

Visiblity	January 1 to April 30					Quantity of dust at 6 feet above ground	Total storms times dust concentration
	Number of dust storms						
	1954	1955	1956	Total			
miles						mg. /cu. ft.	
0 - 0.5	5	9	1	15	5.0		75.0
0.5 - 1	2	1	2	5	1.2		6.0
1 - 3	13	3	2	18	0.5		9.0
Total	20	13	5	38			90.0
	Calendar year						
0 - 0.5	7	9	2	18	5.0		90.0
0.5 - 1	2	2	3	7	1.2		8.4
1 - 3	23	4	9	36	0.5		18.0
Total	32	15	14	61			116.4

Conversion factor from seasonal to annual soil loss therefore is $116.4/90.0 = 1.293$.

¹Contribution from Soil and Water Conservation Research Division, ARS, USDA, with the Kansas Agr. Exp. Sta. cooperating. Department of Agronomy Contribution No. 649. Received Sept. 10, 1959. Approved Nov. 9, 1959.

²Soil Scientist, Western Soil and Water Management Research Branch, SWCRD, ARS, USDA, Manhattan, Kans.

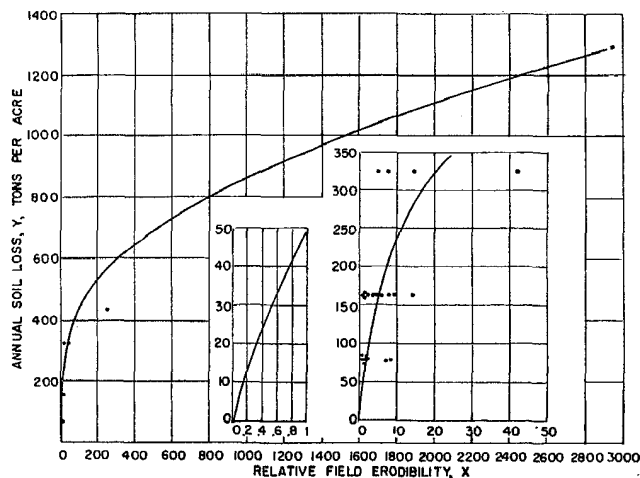


Figure 1—Relationship between annual soil loss and relative field erodibility.

ured depth of soil removal was obtainable from 24 of 69 fields. Figure 1 based on the 24 fields shows the relationship between annual soil loss and the relative field erodibility as determined from major measurable factors that influence it. It is known that the soil loss should reach zero as X reaches zero. Therefore the curve is drawn through the average of data and projected to the point $X = 0, Y = 0$. Since the great majority of the fields had extremely low values of soil loss and relative field erodibility, portions of the graph in the vicinity of these low values are enlarged to indicate more clearly the X and Y values for these portions of the curve. For values of X and Y greater than 0.1 and 5 tons per acre per annum, respectively, the curve fits the equation $Y = aX^b - 1/cd^x$ in which Y is annual soil loss in tons per acre, X is dimensionless relative field erodibility, and $a, b, c,$ and d are constants, which are equal to 140, 0.287, 0.01525, and 1.065, respectively. In view of great inaccuracies in measuring relatively small annual soil losses from depth of soil removal, conversion of the relative field erodibility to annual soil loss based on the curve of figure 1 must be regarded only as highly approximate. A table has been prepared from figure 1 for a more convenient conversion medium.

It will be noted from figure 1 that the annual soil loss of 5 tons per acre, generally chosen as a maximum permissible loss by water erosion in midwestern United States³ corresponds to a relative wind erodibility of about 0.1. An insignificant relative field erodibility by wind has been considered to be less than 0.25 (3). On the basis of figure 1, this corresponds to an annual soil loss of about 15 tons per acre for weather conditions indicated in this paper. The 15-ton per acre annual loss, though significant for water erosion, might be regarded as insignificant for wind erosion for it is known that a substantial proportion of soil removed from denuded wind-eroded areas or fields is returned in uniform layers of dust to nearby nonerodible fields so that a loss from a given field is not a complete loss to an agricultural area. Next season the removal and deposition pattern might be reversed due to rotation of crops and tillage. Soil removed by water erosion, on the other hand, is far less likely to be deposited on adjacent nonerodible land.

Field erodibility of less than 0.25 is associated with no distinct visible effects of soil movement (tables 2 and 3). This does not mean that there is no soil loss, but that the loss is too small to be detected by visual observation. On the basis of 2 million pounds of soil per acre to 6-inch depth, it is equal to less than 0.11-inch depth of soil. Depths such as this cannot be measured by conventional field methods.

Distinctly visible soil removal was associated with quantities of annual soil loss greater than 15 tons per acre. Slight quantities of soil removal not sufficient to kill winter wheat in boot stage corresponded to a maximum relative field erodibility of about 1.0 (table 3). The projected curve of figure 1 indicates that the relative field erodibility of 1.0 corresponds to an annual soil loss of about 50 tons per acre, a quantity not measurable from depth of soil removal.

Other categories of quantity of erosion, all of which are measurable from depth of soil removal, are listed in table 3 together with corresponding values of annual soil loss and relative field erodibility. These categories are purely arbitrary.

³Workshop on slope-practice. By representatives of the SCS, USDA; Soil and Water Conserv. Research Division of ARS, USDA; State Experiment Stations; and Extension Service. Purdue University, Lafayette, Ind. July 19-20, 1956, 12 pages, mimeo.

Table 2—Relation between relative field erodibility, seasonal and annual soil loss, and effects of erosion for 1954 through 1956.

Field No.	Relative field erodibility	Measured soil loss*		Field No.	Relative field erodibility	Measured soil loss*		Field No.	Relative field erodibility	Measured soil loss*	
		Seasonal	Annual			Seasonal	Annual			Seasonal	Annual
		tons/A.	tons/A.			tons/A.	tons/A.			tons/A.	tons/A.
1	5.0	250	324	24	0.5	62	80	47	0.18	†	†
2	14.0	125	162	25	0.26	†	†	48	0.23	†	†
3	0.22	†	†	26	0.37	†	†	49	0.01	†	†
4	2.5	†	†	27	0.08	†	†	50	0.34	†	†
5	1.2	62	80	28	0.22	†	†	51	0.55	†	†
6	2.0	125	162	29	0.40	†	†	52	1.30	62	80
7	2950.0	1000	1293	30	0.34	†	†	53	0.21	†	†
8	14.5	250	324	31	0.11	†	†	54	1.9	†	†
9	0.05	†	†	32	0.10	†	†	55	0.01	†	†
10	0.14	†	†	33	0.44	†	†	56	0.2	†	†
11	9.5	125	162	34	0.09	†	†	57	0.1	†	†
12	0.18	†	†	35	7.0	62	80	58	0.1	†	†
13	1.85	62	80	36	0.21	†	†	59	0.1	†	†
14	230.0	333	430	37	0.20	†	†	60	42.0	250	324
15	5.7	125	162	38	0.15	†	†	61	0.55	125	162
16	0.23	†	†	39	6.0	125	162	62	7.1	250	324
17	0.22	†	†	40	1.8	62	80	63	9.5	125	162
18	0.97	†	†	41	0.06	†	†	64	1.1	125	162
19	2.3	†	†	42	0.14	†	†	65	0.1	†	†
20	7.5	62	80	43	0.35	†	†	66	0.1	†	†
21	0.88	†	†	44	5.3	125	162	67	0.1	†	†
22	1.6	125	162	45	0.93	†	†	68	0.1	†	†
23	0.7	62	80	46	0.01	†	†	69	0.2	†	†

* Winter wheat was killed in all cases indicating measurable soil loss. † No distinct visible effects of soil movement.

† Distinct visible effects of soil removal but not measurable from depth of removal and not sufficient to kill wheat in boot stage.

Table 3—Relationships among quantity of wind erosion, effects of erosion, and relative field erodibility.

Quantity of erosion	Description of erosion	Annual soil loss* tons/acre/yr.	Relative field erodibility
None to insignificant	No distinct visible effects of soil movement	Less than 15	Less than 0.25
Slight	Soil movement not sufficient to kill winter wheat in boot stage	15 to 50	0.25 to 1.0
Moderate	Removal and associated accumulations to about 1-inch depth sufficient to kill wheat in boot stage	15 to 167	1.0 to 5
High	About 1 to 2-inch removal and associated accumulations	167 to 333	5 to 20
Very high	2 to 3-inch removal with small dune formations	333 to 500	20 to 150
Exceedingly high	More than 3-inch removal with appreciable piling into drifts or dunes	More than 500	More than 150

* Occurring in the vicinity of Garden City, Kansas, during 1954 through 1956.

Discussion

The rate of annual soil loss to which the relative field erodibility may be converted is the quantity of soil that would be removed under climatic conditions that occurred in the vicinity of Garden City, Kansas, during 1954 through 1956. Those years and that location are standard for this conversion. Any other period of years or another location probably would have given different values of

annual soil loss for given values of relative field erodibility. It is important therefore to describe the relative severity of wind erosion at that location during that period. One way of describing it is by number and severity of dust storms as shown in table 1.

Permissible or insignificant soil losses not exceeding 15 tons per acre per annum are based on the following important considerations:

1. Maintenance of adequate soil depth for lasting crop production.
2. Prevention of damage to home buildings, wind-breaks and shelterbelts, ponds, ditches, terraces, etc.
3. Maintenance of original soil texture by prevention of soil sorting by wind.
4. Prevention of seed and crop losses from direct injury of wind erosion.

The goal should be to reduce erosion to a permissible or insignificant quantity tentatively set at 15 tons per acre per annum.

LITERATURE CITED

1. Chepil, W. S. Soil conditions that influence wind erosion. USDA Tech. Bull. 1185. 1958.
2. ———. Wind erodibility of farm fields. J. Soil Water Conserv. 14:214-219. 1959.
3. ———, and Woodruff, N. P. Estimations of wind erodibility of field surfaces. J. Soil Water Conserv. 9:257-266. 1954.
4. ———, and ———. Sedimentary characteristics of dust storms: visibility and dust concentration. Am. J. Sci. 255:104-114. 1957.
5. ———, and ———. Estimations of wind erodibility of farm fields. USDA Prod. Res. Rpt. 25. 21 pp. 1959.