Wind Erodibility of Farm Fields

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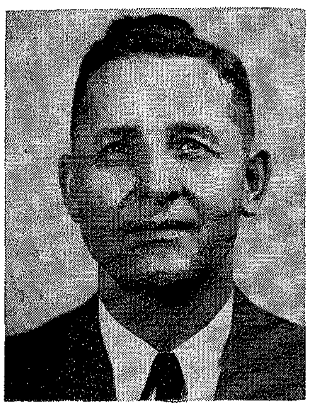
The author indicates how width of field is interrelated with other major factors that influence erosion of soil by wind. He indicates too how the wind erodibility of any field or field strip may be determined for any soil, surface condition, and wind velocity and direction. Graphs and alignment charts are presented for convenient determination of field erodibility or of conditions required to reduce the field erodibility to any degree.

THIS is one of a series of papers based on studies to develop a convenient method of estimating relative susceptibility of farm fields to erosion by wind. Previously four major factors have been approximately evaluated (4, 5). They are soil cloddiness, quantity of crop residue or vegetative cover on the surface, surface roughness, and susceptibility of the soil crust to abrasion by bouncing soil particles.

This paper presents information particularly on the method of evaluating a fifth factor—the width of field or field strip. The original data on which this evaluation is based are contained in previous publications (3, 1, 2). Those data are a result of measurements of the rate of soil movement at different distances downwind across fields and field strips during the time they were being eroded by wind.

The purpose of developing a method to evaluate the influence of size of field is to give the soil conservationist a convenient device for determining what width of fields or field strips is necessary under any condition to reduce the rate of erosion to any degree. It is believed that evaluations such as these will give a better understanding of wind erosion and will serve as tools for determining more conclusively what conditions are necessary for its control.



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This is primarily a numerical rather than descriptive analysis of the subject. Many of those to whom the paper may be of interest may be discouraged by this type of analysis. The numerical analysis by use of charts has been chosen because it is believed it can best yield information that can be interpreted but one way only. Ramifications arising from use of the charts rest with the people who will use them.

The Influence of Width of Field

Soil movement across wind-eroding fields may be likened to an avalanche rolling down the mountain. The avalanche grows in volume as it rolls downhill. So too does soil movement across eroding fields. The rate of soil movement on the windward side of the field is zero. From this point it increases more or less proportionately with distance downwind until, if the field is large enough, a maximum rate is reached. The distance required for soil flow to reach the maximum on a given soil is the same for any erosive wind. It varies only and inversely with erodibility of a field surface. That is, the more erodible the surface, the shorter the distance in which maximum flow is reached. The relationship between wind erodibility and distance required for soil flow to reach a maximum rate is shown in Figure 1.

The maximum rate of soil flow in a given wind is remarkably uniform for all field surfaces. It is equal to about 2 tons per rod width per hour for a 40-m.p.h. wind velocity at 50 feet above an unsheltered, level terrain. The rate of soil flow beyond this point on the terrain is constant. It represents the maximum concentration of moving soil particles that a wind of this velocity can carry. The maximum rate of flow is seldom reached because fields are usually limited in size.

The increase in rate of soil flow with distance downwind across an unsheltered wind-eroding area is called *soil avalanching*. Its recognition in a way has resulted in adoption of various forms of strip cropping for wind erosion control.

Wind erodibility is expressed in this paper in terms of relative quantity of erosion and as rate of soil flow. The use of the two systems is unavoidable. It arose from erodibility measurements in a wind tunnel and in the field. In a tunnel the rate of soil flow for cultivated land drops rapidly with duration of exposure so that it can be expressed only in terms of quantity of soil removed from unit area before soil removal has ceased. In the field, due to much larger area and consequent substantial abrasion from bouncing soil grains, erosion does not

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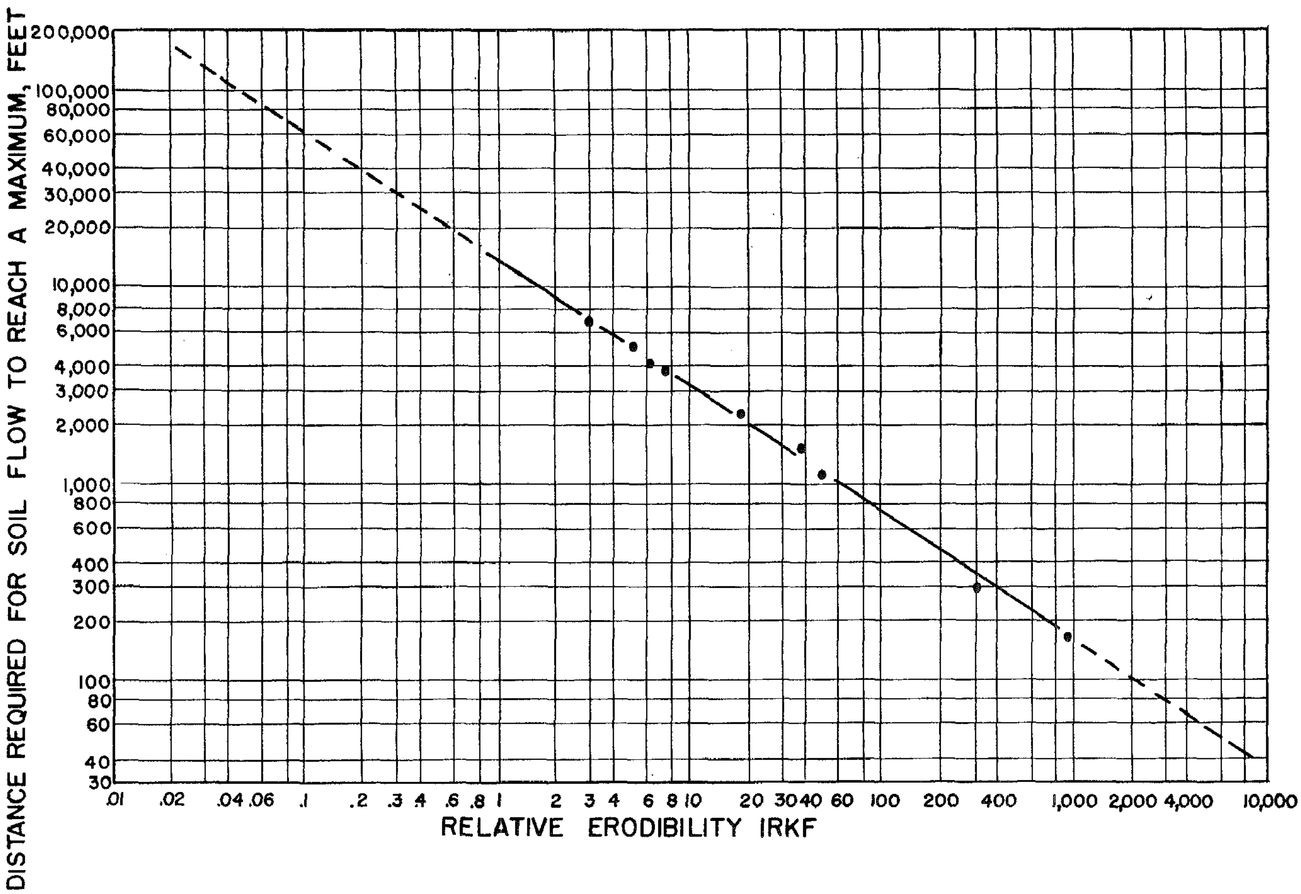

Figure 1. Relation between distance for soil flow to reach a maximum and relative wind erodibility IRKF.

cease except from very small areas so that wind erodibility can be expressed only in terms of rate of soil flow.

The wind velocity level on which this analysis is based is 40 m.p.h. at 50 feet above a smooth, level and unsheltered terrain. According to Zingg (7), this velocity at Dodge City, Kansas, occurs once in 2 years on the average for a 6-hour period during April. This wind velocity level is taken as standard in determining relative field erodibility. Little information is available on wind velocity level for various geographic locations and on its influence on wind erodibility. It is therefore not included in the present analysis.

Factors Influencing Wind Erosion

The quantity of wind erosion E may be expressed by a generalized equation

$$E = IRKFBWD \qquad \textit{(equation 1)}$$

in which, I = Soil cloddiness factor
R = Crop residue factor
K = Ridge roughness equivalent factor
F = Soil abradability factor
B = Wind barrier factor
W = Width of field factor
D = D wind direction factor.

There are other factors that influence the quantity of erosion, but the above appear to be the major ones. Erodibility as determined from factors I and F is soil erodibility; that based on additional factors R and K measures the surface erodibility; and that based on all recognized factors determines the field erodibility.

An alignment chart and table have been drawn up in a previous publication from which the influence of factors I, R, K, and F may be determined (5). Also, it was shown how procedures may be reversed to determine what conditions of I, R, K, and F are necessary to reduce the quantity of erosion to any degree.

Determining the Influence of Wind Barriers on Erodibility of Various Sizes of Fields

The portion of the field that is completely sheltered by any barrier such as stubble, crop, hedge, or tree windbreak that may be present on the windward side of a field must be subtracted from the portion that is not. Insufficient information is available on the relative influence of various types and heights of barriers on erosion of soil by wind. Therefore, an evaluation of wind barrier factor B in relation to erodibility of various sizes of field or field strip must be only approximate at the present time. According to Woodruff and Zingg (6), distance of full protection from wind erosion can be expressed approximately by

$$d = h(17 \frac{v_o}{v}) \qquad \textit{(equation 2)}$$

in which d is distance of full protection from erosion, h is height of barrier expressed in same units of measure as distance d, v_o is the minimum wind velocity at 50-foot height required to move the most erodible soil fraction, and v is the actual velocity at 50-foot height. The minimum velocity required to initiate soil movement on a smooth, bare surface after erosion has been initiated and before wetting and subsequent surface crusting by rain is about 21.5 m.p.h. at 50 feet above a smooth and level terrain. Consequently, equation 2 for this condition, which is rather common in spring before the land is cultivated and when wind erosion is most likely to occur, may be expressed by

$$d = \frac{365\,h}{v} \qquad \textit{(equation 3)}$$

The chart of Figure 2, developed from equation 3, can be used to determine distance of full protection from wind erosion. Corresponding values of height of barrier and distance of full protection are aligned along a vertical axis. Only the influence of barriers up to 4 feet in height, such as stubble or crop, are given. The distance of full protection from barriers taller than 4 feet can be computed readily from equation 3.

Distance d is distance along prevailing direction of wind. It is the distance that is fully protected under a wind velocity of 40 m.p.h. at 50-foot height. The total distance across the field along prevailing direction of wind minus distance d indicates distance d_t that is unprotected from the wind. If the barrier such as stubble is knocked down by tillage, the completely sheltered zone d would be virtually eliminated and erosion-susceptible fields or field strips should be that much narrower to have the same field erodibility. On the other hand, if the wind barrier is much taller than the stubble, the completely sheltered zone would be considerably greater, as shown by Figure 2 and equation 3, and the erosion-susceptible fields or field strips could be widened considerably and still be able to keep wind erodibility down to a tolerable degree. The field erodibility is dependent directly on distance d_t, that is, on distance (measured along prevailing direction of wind) that is not protected from the wind.

Determining the Influence of Width of Field and Direction of Prevailing Wind

Evaluation of factors W and D may be made from the chart shown in Figure 3. This chart was developed from Figure 1 and from data contained in two previous publications (2, 5). The procedure simply is to convert the relative surface erodibility based on factors I, R, K, and F to relative field erodibility based on additional factors B, W, and D by use of Figure 3.

To convert the relative surface erodibility IRKF to field erodibility IRKFBWD, proceed as follows:

1. Find IRFK value on the left side of chart (Figure 4).
2. Move from this point to the right along or between and parallel with thick erodibility lines until the unprotected distance d_t of field along prevailing direction of wind shown on top of the chart is reached.
3. Read IRKFBWD value for this point by moving to the extreme right along or between and parallel with thin, co-ordinate lines.

The procedure with Figure 3 can be reversed to determine the unprotected distance across the field along prevailing direction of wind required to reduce the field erodibility to any degree.

It will be observed that the IRKFBWD values in Figure 3 remain constant for any width of field down to some critical width, depending on the relative erodibility level of the field. As the field is narrowed still more, the rate of soil flow and hence the relative erodibility IRKFBWD drops—the drop being slow at first but becoming progressively more rapid and finally attaining a constant rate.

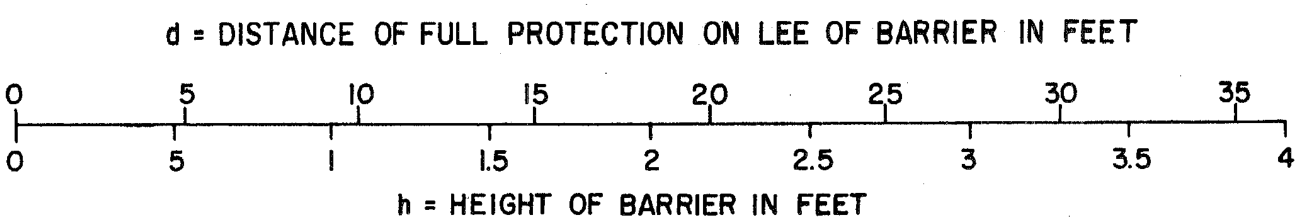

Figure 2. Alignment chart for determining distance of full protection from wind erosion afforded by barriers of various heights exposed to a standard wind velocity level.

These relationships hold true for all conditions of field surface but at different levels depending on the relative surface erodibility IRKF.

Field erodibility is governed by the maximum unprotected distance across the field along prevailing direction of wind. If only the dimensions of the field or field strips

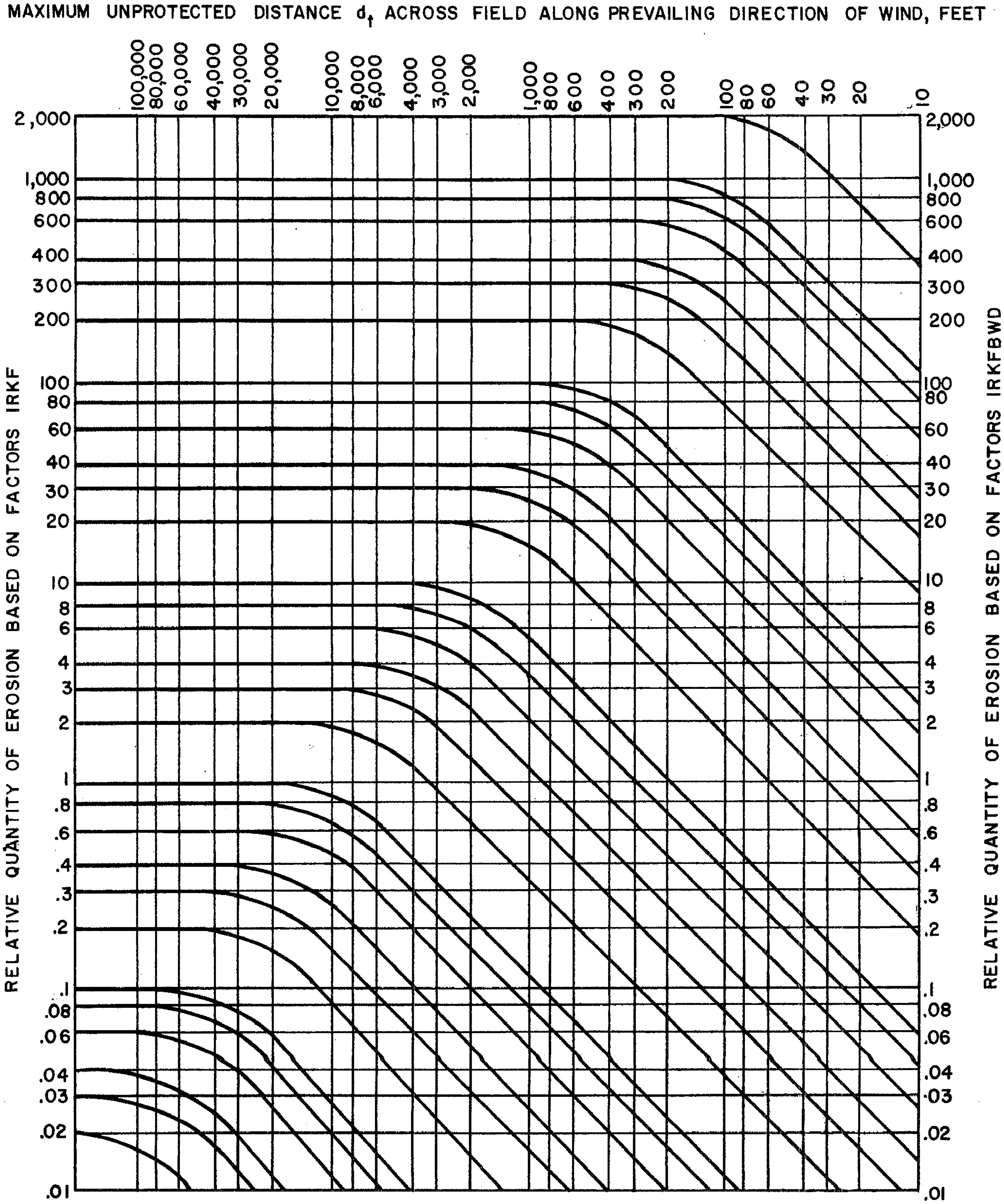

Figure 3. Chart showing the relationship between relative quantity of wind erosion and width of field along prevailing direction of wind.

are known, this distance can be determined conveniently by use of Figure 4 as follows:

> A straightedge is passed through the width of field or field strip on line EF and through value of angle of deviation of prevailing wind direction from perpendicular to field or field strip on line CD. The maximum distance across the field or field strip along prevailing direction of wind lies at a point where the straightedge crosses line AB. This distance minus the distance d along prevailing direction of wind protected by any barrier that might exist on the windward side of field or field strip is equal to the maximum unprotected distance d_t across the field or field strip along prevailing direction of wind.

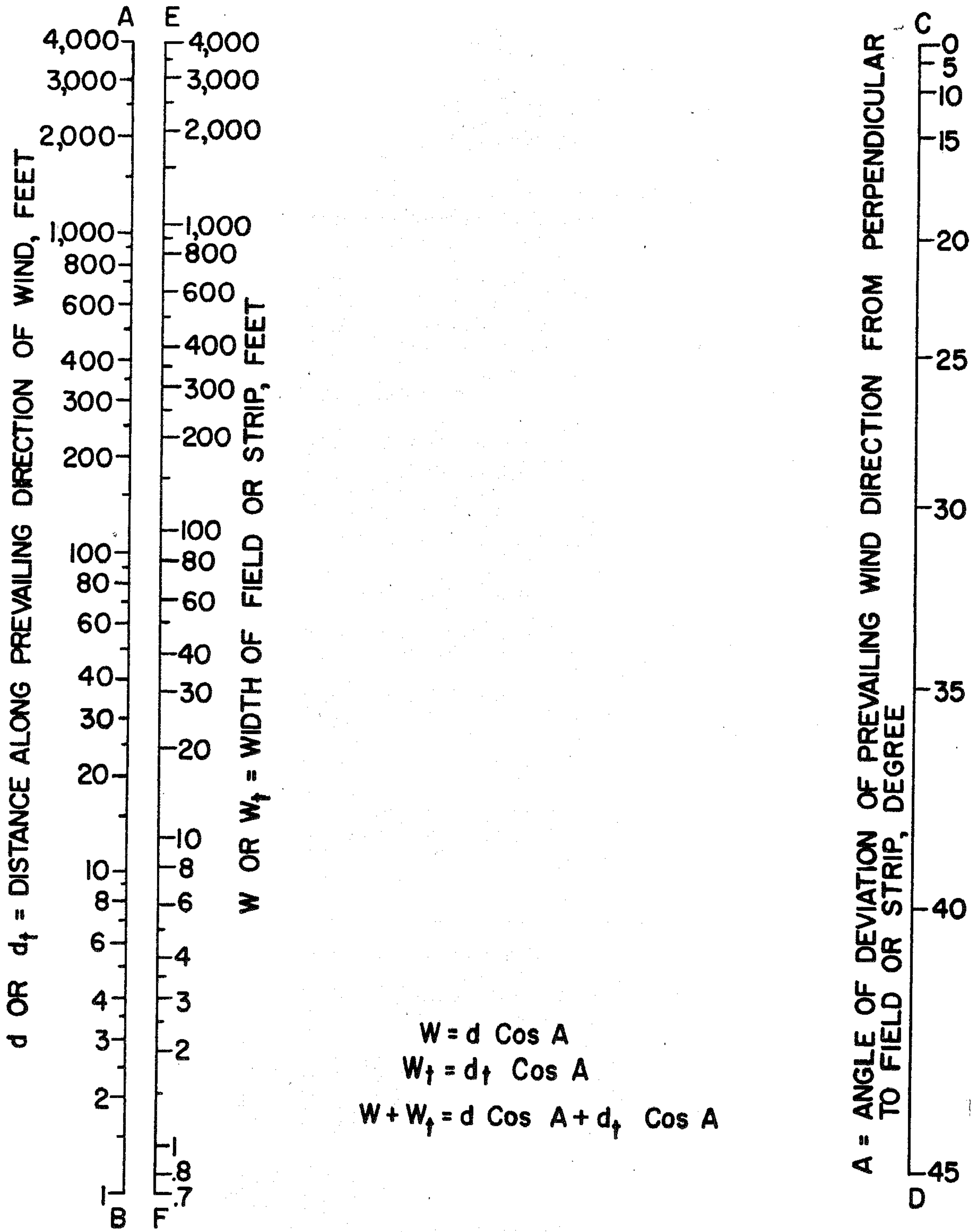

Figure 4. Alignment chart for determining distance across field or strip along prevailing direction of wind from the width of field and the direction of wind.

Figure 4 can also be used to determine the required width of field or field strip from distances (d and d_t) along prevailing direction of wind and from the angle of deviation of prevailing wind from perpendicular to field or strip. Simply pass a straightedge through distance d, d_t, or $d + d_t$ on line AB and angle of deviation A on line CD and read the desired width of field W, W_t, or $W + W_t$ on line EF at a point where the straightedge crosses it.

Example of Use to Determine Field Erodibility or to Determine Width of Field Required to Reduce Field Erodibility to Any Degree

Suppose that the field is 1,000 feet wide along east-west direction and 2,640 feet along the north-south direction; stubble 1 foot high surrounds the field; the prevailing or average wind direction is oriented along the west-northwest and east-southeast axis; and as determined by procedure described by Chepil and Woodruff (5), surface erodibility IRKF is 2.

First, we shall determine the field erodibility. The angle of deviation of prevailing wind direction from perpendicular to broad side of the field or the west-northwest and east-southeast axis is 22.5 degrees. As indicated before, the field width $W_t + W$ is 1,000 feet. Therefore distance $d_t + d$ across the field along prevailing direction of wind, according to Figure 4, is about 1,100 feet. Distance d, that fully protected by the 1-foot stubble, according to Figure 2, is approximately 8 feet. There, the unprotected distance d_t is $1{,}100 - 8 = 1{,}092$ feet. Moving from IRKF value of 2 on the left hand side of Figure 3 along the thick erodibility line till the maximum unprotected distance d_t of 1,092 feet shown on top of the chart is reached, then moving horizontally to the right, shows the relative field erodibility IRKFBWD of about 0.42.

Next, we shall determine what width of field is required under the prevailing surface conditions to reduce the field erodibility to some desired degree. Suppose it is desired to reduce the field erodibility to a negligible value of 0.25. According to Figure 3, the maximum unprotected distance d_t across the field along prevailing direction of wind would have to be about 750 feet to reduce erodibility IRKF of 2 to IRKFBWD of 0.25. Distance d protected by the 1-foot stubble is 8 feet and the total distance $d_t + d = 758$ feet. For prevailing wind velocity deviating 22.5 degrees from perpendicular to the broad side of the field, the required width of field for the existing surface conditions, according to Figure 4, is approximately 680 feet. Of course, the field erodibility may be reduced more conveniently by other means than reducing the width of field. Such other means may be increasing cloddiness I, residue cover R, surface roughness K, or height of barriers B. The tables and alignment charts of this and previous papers will indicate by how much the various factors need to be modified to reduce the field erodibility to any degree.

Conclusion

Alignment charts and formulas evaluating various wind erosion factors listed in equation 1 show average effects of variable conditions existing in the field. The residue factor so far has been evaluated only for quantity above the surface of the ground regardless of kind. The influence of orientation of residue in relation to the ground surface and direction of wind is hardly explored. Little is known of the influence of various types of barriers on the quantity of soil erosion by wind. Little information, too, is available on the influence of general velocity level and average direction of wind at various geographic locations. Effects of soil moisture conditions on wind erodibility have been hardly explored. Further research on these and related problems should result in refinements of the present methods of evaluation. The series of papers of which this one is a part indicates primarily the general framework upon which research information on conditions required to control wind erosion can be built.

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