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 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.

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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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

\[ E = IRKFBWD \]  \hspace{1cm} (equation 1)

in which, I = Soil clodliness 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
\[ d = h(17 - \frac{v}{v_0}) \]  
(equation 2)
in which \( d \) is distance of full protection from erosion, \( h \) is height of barrier expressed in same units of measure
as \( d \), \( v_0 \) 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 mini-
mum 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 cul-
tivated and when wind erosion is most likely to occur,
may be expressed by
\[ d = \frac{365 h}{v} \]  
(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 verti-
cal 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 com-
pletely 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 con-
siderably 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 di-
rection 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 de-
termine 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 Fig-
ure 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 progres-
sively more rapid and finally attaining a constant rate.
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.

\[
W = d \cos A \\
W_t = d_t \cos A \\
W + W_t = d \cos A + d_t \cos A
\]

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 d1) 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, d1, or d + d1 on line AB and angle of deviation A on line CD and read the desired width of field W, Wt, or W + Wt 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; and as determined by procedure described by Chepil and Woodruff (5), surface erodibility IRKF is 2.

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 d1 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.

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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.

REFERENCES