In the Great Plains

Prevailing Wind Erosion Direction

Erosion of agricultural lands by wind is a serious problem in the Great Plains. To reduce the hazard of soil movement by wind, wind barriers of various types and directional orientation have been used. This analysis of direction and frequency of winds of different velocities at 59 locations in a 12-state region provides a rational basis for planning directional orientation of wind barriers and erosion-reducing tillage operations to provide the most effective wind erosion protection.

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PREVAILING wind erosion direction is that direction in which the greatest amount of soil is moved. The amount of soil moved is influenced by the duration and the velocity of wind from different directions.

Wind barrier strips, whether they be soil ridges, crop strips, crop rows, or tree windbreaks, protect the greatest area of ground and protect the ground the most if they run at right angles to wind direction; they give the least protection if they run parallel with wind direction. This is because the amount of erosion caused by wind is directly proportional to the longest distance across an eroding area, as measured along the prevailing wind erosion direction *(1)*. The more closely the wind erosion direction is at right angles to the wind barrier strips, the shorter is the distance along the prevailing wind erosion direction between the strips. Therefore, the goal of effective wind erosion control is to run crop strips, rows, and soil ridging implements as nearly as possible at right angles to the prevailing wind erosion direction. Knowledge of the prevailing wind erosion direction is necessary to make the most effective use of strip cropping, shelterbelt plantings, and emergency erosion-reducing practices.

The greater the relative amount of erosion along the prevailing wind erosion direction, the greater the benefits from running the barriers at right angles to that direction. Therefore, it is important to know both the prevailing wind erosion direction and the percentage of erosion along the prevailing wind erosion direction.

The amount of erosion caused by wind on any field is the same whether the wind is blowing from one direction or whether it comes from the opposite direction *(6)*. Therefore, for the purpose of this analysis, the 16 principal directions for which wind data are available have only 8 equivalent wind erosion directions: N-S, NNE-SSW, NE-SW, ENE-WSW, E-W, ESE-WNW, SE-NW, and SSE-NNW. In this article, any reference to the prevailing wind erosion direction means that prevailing wind erosion is coming from a particular direction and from its opposite direction.

Method of Analysis

Used in the analysis presented in this article were data on average wind speed in miles per hour and on percent duration of the wind from each of the 16 principal directions at 59 locations in and east and west of the Great Plains. These data were obtained from the records of the United States Weather Bureau and the Department of the Air Force. Periods covered by the records at individual locations ranged from 2 to 13 years; the average length of period covered by records for all locations was 5.8 years. Published records for longer periods were not available.

Wind erosion roses (graphical representations of the relative amount of wind erosion from different directions) were constructed from the data (figure 1). Then the roses were used to estimate the prevailing wind erosion direction and the percent of erosion that occurs along the prevailing wind erosion direction at each location (figure 2).

The relative length of each line of a rose in figure 1 indicates the relative amount of erosion by wind, and the direction of each line indicates the average windstorm direction, traveling from the outside to the center of the rose. The relative length, l, of each of the 16 lines of the wind erosion rose was computed by first multiplying percent duration, F, by wind velocity cubed, V^3, since the rate of wind erosion varies as the cube of wind velocity *(2, 4)*; then each of the 16 products was divided by the sum of the 16 products and each of the resulting quotients was multiplied by X, the total length of lines of the wind erosion rose, thus:

$$l = X\,[FV^3]\,[\Sigma(FV^3)]^{-1} \qquad \text{equation 1}$$

Lengths l and X hold the same ratio to each other regardless of the scale or unit of length used. A scale most convenient for drawing was used.

The prevailing wind erosion direction was obtained graphically by drawing a straight line through the longest distance, l_p, across the general area outlined by the wind erosion rose. The area of the rose was taken as that area bounded by the shortest continuous line joining the outer points of the radiating lines of the rose. A point on the prevailing wind erosion direction line in figure 2 indicates a geographic location and also divides the relative amount of erosion from opposite directions.

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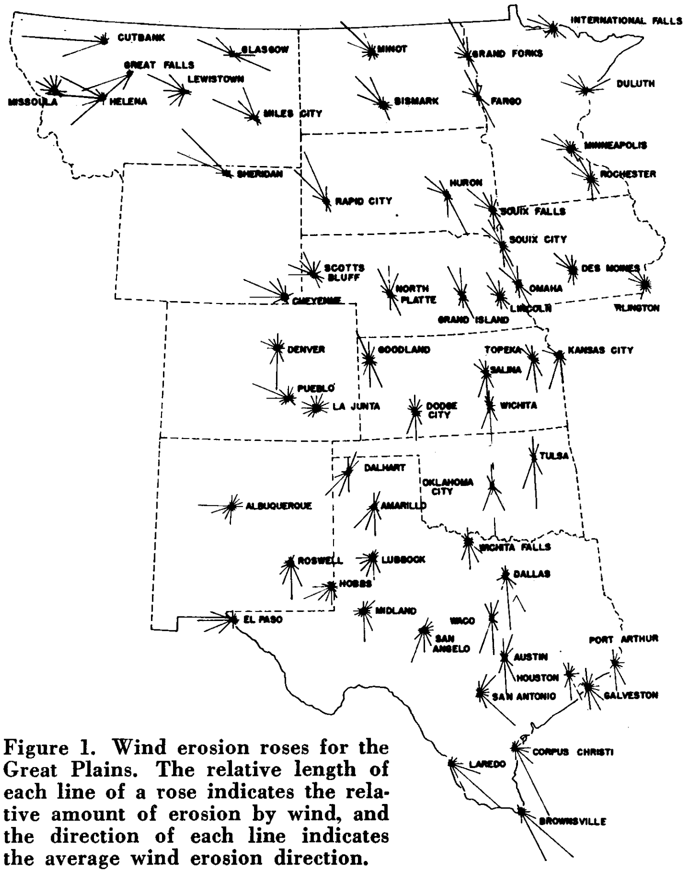

Figure 1. Wind erosion roses for the Great Plains. The relative length of each line of a rose indicates the relative amount of erosion by wind, and the direction of each line indicates the average wind erosion direction.

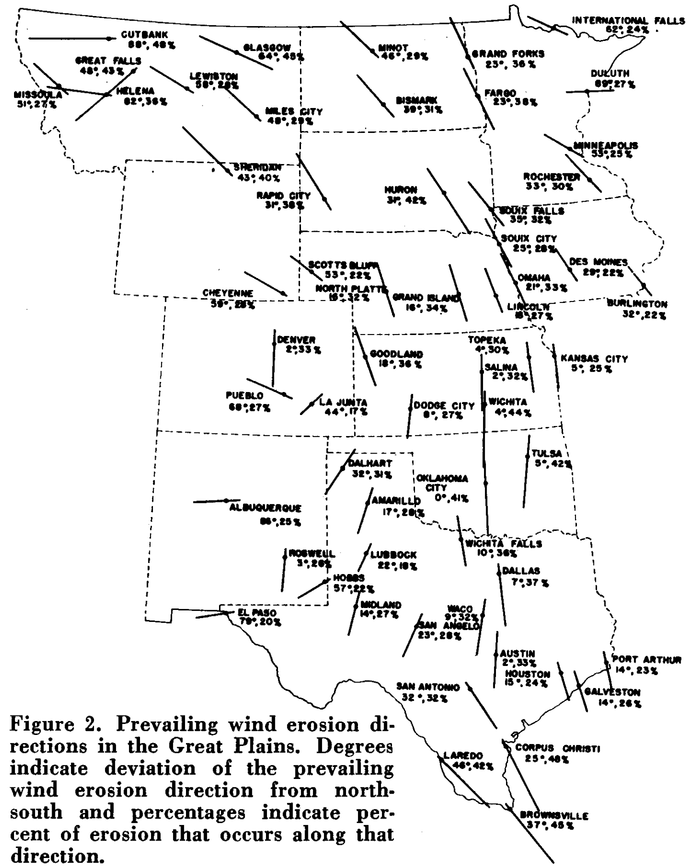

Figure 2. Prevailing wind erosion directions in the Great Plains. Degrees indicate deviation of the prevailing wind erosion direction from north-south and percentages indicate percent of erosion that occurs along that direction.

The prevailing wind erosion direction was expressed as degrees deviation from north-south wind erosion direction (figure 2). Values for this deviation from the north-south direction may, of course, vary only from 0 to 90 degrees.

Computation of the prevailing wind erosion direction is extremely complicated and, therefore, the graphical method previously described was used. This method was considered accurate for all practical purposes.

The relative amount of erosion along the prevailing wind erosion direction, E_p, was expressed as a percent of erosion from all directions (figure 2), thus:

$$E_p = 100\ l_p / X \qquad \text{equation 2}$$

Since the wind erosion rose is based on the equivalent of eight wind erosion directions, an E_p value of $100/8 = 12.5$ percent would indicate that the rose is perfectly symmetrical and that there is no prevailing wind erosion direction. The other extreme would be an E_p value of 100 percent, indicating that wind erosion occurs only along one wind erosion direction covering 11.25 degrees (1/32 of a circle) each side of that direction. Any value of E_p above 12.5 percent would indicate that a prevailing wind erosion direction exists.

General Findings

Throughout the Great Plains, the wind erosion roses (figure 1) and the prevailing wind erosion directions (figure 2) present a rather definite pattern. In most of Texas, the southerly winds predominate; they gradually decrease in frequency and/or intensity as one moves north to about the Kansas-Nebraska border where the northerly and southerly winds are almost equal. Northward from this border the northerly winds begin to prevail and to shift gradually to a northwesterly direction in the Dakotas and eastern Montana and to westerly in western Montana. In the extreme northwestern part of Texas, the southwesterly winds predominate, while in most of New Mexico, the westerly winds seem to prevail.

Throughout the region, there are several locations where wind erosion directions seem to depend more on local conditions than on broad atmospheric influences. Some notable examples are Pueblo, Colorado, where the prevalence of westerly winds is due to the gap in the mountain range to the west, and Great Falls, Montana, where the prevalence of the southwesterly winds may be due to the influence of the Missouri River Valley, which stretches in that direction. In general, the wind erosion roses are quite asymmetrical. The La Junta, Colorado, wind erosion rose is the most nearly symmetrical.

Application of Results

The existence of a prevailing wind erosion direction means that there is an optimum direction to which field strips, shelterbelts, emergency erosion control tillage, and crops should be oriented for maximum wind erosion control. This optimum direction is at right angles to the prevailing wind erosion direction shown in figure 2. The more nearly at right angles the wind barrier strips are to the prevailing wind erosion direction, the shorter is the distance across the field strip along the prevailing wind erosion direction and the less the amount of erosion that will occur (*3*).

If the deviation of the prevailing wind erosion direction is less than 45 degrees from the north-south direction, the wind barrier strips should run more closely along the east-west direction. If, on the other hand, the deviation is more than 45 degrees, the strips should run more closely along the north-south direction. Also, the greater the percent of erosion along the prevailing wind erosion direction, E_p, as indicated by the relative length of lines in figure 2, the more certain is the requirement that strips run at right angles to that direction. Considering these facts and assuming that strips can be laid only north-south or east-west, the information in figure 2 would indicate that wind barrier strips should run north-south in Montana, in western North Dakota, and in eastern Wyoming; they should run east-west in most of the Great Plains (including 75 percent of the locations). The direction wind barrier strips run appears to be least important in New Mexico, in a small part of western Texas, in southeastern Colorado, and in eastern Minnesota and Iowa.

Width alone does not determine the erodibility of a field or field strip; the prevailing wind erosion direction and the presence or absence of adjoining wind barriers must be taken into account too *(1)*. Regardless of how narrow the field strip might be, if wind direction is parallel to its length, the strip would be almost as erodible as a large field with a width equal to the length of the strip. Furthermore, if any barrier is present on the windward side of the field, the distance D_b (along the prevailing wind erosion direction) which it fully shelters from the wind must be subtracted from the total distance D_f (along the prevailing wind erosion direction) across the field to determine the longest unsheltered distance across the field along the prevailing wind erosion direction, designated by L. This is the distance that directly determines the amount of erosion caused by wind.

Therefore, to determine the amount of erosion on any field, it first is necessary to determine the total longest distance (sheltered and unsheltered) across the field along the prevailing wind erosion direction, D_f. This can be determined from the width of field strip, W_f, and from the angle of deviation of the prevailing wind erosion direction from right angles to the field strip, A, since it is known *(3)* that:

$$D_f = W_f/\text{Cos } A \quad \text{equation 3}$$

Conversely, the required width of field strip or the required distance between wind barriers, W_f, which is necessary to keep erosion down to some tolerable limit, can be determined from the distance across the field strip along the prevailing wind erosion direction, D_f, and from the angle of deviation of the prevailing wind erosion direction

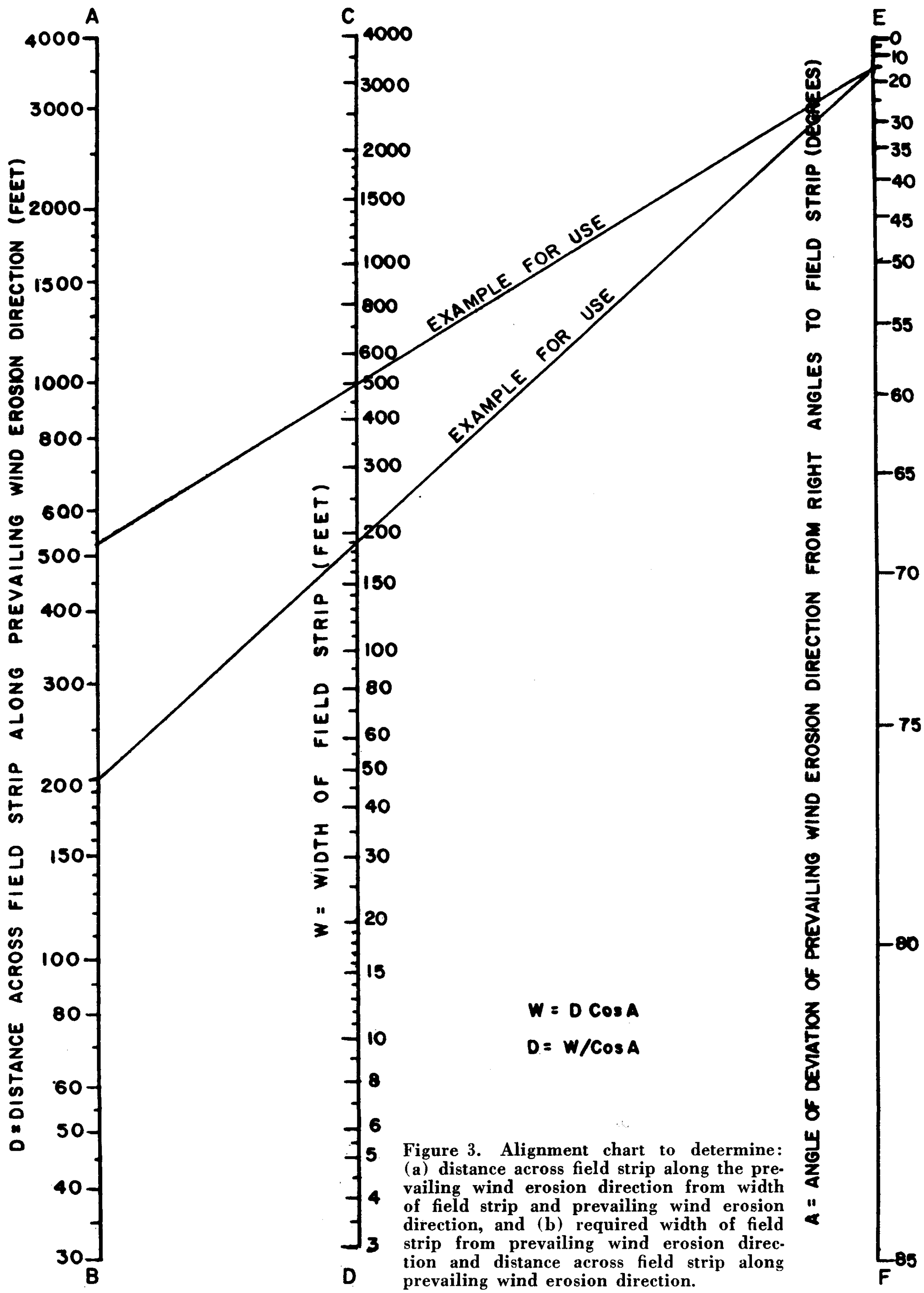

Figure 3. Alignment chart to determine: (a) distance across field strip along the prevailing wind erosion direction from width of field strip and prevailing wind erosion direction, and (b) required width of field strip from prevailing wind erosion direction and distance across field strip along prevailing wind erosion direction.

from right angles to the strip, A, according to transposed equation 3:

$$W_f = D_f \text{ Cos } A \quad \text{equation 4}$$

Similarly, the sheltered distance across the field along the prevailing wind erosion direction, D_b, and the width of strip sheltered by a wind barrier, W_b, can be determined from:

$$D_b = W_b/\text{Cos } A \quad \text{equation 5}$$

$$\text{and } W_b = D_b \text{ Cos } A \quad \text{equation 6}$$

Likewise, the width of strip unsheltered by the barrier, $W = W_f - W_b$, the unsheltered distance along the prevailing wind erosion direction, $L = D_f - D_b$, can be determined from:

$$W = D_f \text{ Cos } A - D_b \text{ Cos } A \quad \text{equation 7}$$

$$L = W_f/\text{Cos } A - W_b \text{ Cos } A \quad \text{equation 8}$$

An alignment chart (figure 3) can be used more conveniently than equations 3 through 8 to determine any one of the three variables if the other two are known. To avoid superfluity, W_f or W_b are shown merely as W and D_f or D_b as D in figure 3.

For example, suppose a field at Grand Island, Nebraska, has a width W_f along the north-south direction of 500 feet, a length along the east-west direction of 2,640 feet, and a tree windbreak that shelters it 200 feet along the prevailing wind erosion direction, D_b. Figure 2 reveals that the angle of deviation of prevailing wind erosion direction from the north-south direction at this location is 16 degrees. This is angle A—the degrees deviation of the prevailing wind erosion direction from perpendicular to the broad side (east-west) of the field. The following additional information can be obtained from figure 3:

$D_f = 525$ feet. (Found by placing a straightedge on line EF at $A =$ 16 degrees on line CD at $W_f =$ 500 feet. This projects to about 525 feet on line AB, as shown by the upper example line in figure 3.)

$W_b = 190$ feet. (Found by placing a straightedge on line AB at D_b $= 200$ feet and on line EF at $A = 16$ degrees and reaching W_b at the intersection of the straightedge and line CD, as shown by the lower example line in figure 3.)

Therefore, the longest unsheltered distance across the field along the prevailing wind erosion direction, L, is equal to $D_f - D_b$ or $525 - 200 = 325$ feet.

In the foregoing computations, the longest unsheltered distance along the prevailing wind erosion direction across a field is considered a criterion of the wind erodibility of the field *(5)*.

The higher the percent erosion along the prevailing wind erosion direction, E_p, the greater is the degree of erosion control gained as the wind barrier strips approach right angles to the prevailing wind erosion direction. Moreover, the higher the percent E_p, the less is the degree of erosion control as the wind barrier strips approach parallelization with the prevailing wind erosion direction. For example, assuming that all factors other than percent E_p at La Junta, Colorado, and Wichita, Kansas, are equal, narrower intervals between barrier strips would be required for wind erosion control at La Junta with an E_p of 17 percent than at Wichita with an E_p of 44 percent if the strips run at right angles or nearly at right angles to the prevailing wind erosion direction. But if the strips run parallel or nearly parallel with the prevailing wind erosion direction, then wider intervals between strips could be used at La Junta than at Wichita to gain equal protection from wind erosion. Thus, the effect of E_p varies, depending on the orientation of the field.

Since the influence of E_p varies, no simple method of evaluating it is possible. Therefore, no suggestions are given at the present time for using it in determining field erodibility at different locations. In estimating field erodibility, it is assumed for the present that E_p has no influence on erodibility.

The relative values of E_p at different locations serve another purpose: They indicate the relative degree of benefit from wind barrier strips running as nearly as possible at right angles to the prevailing wind erosion direction. Thus, at Wichita, Kansas, with E_p equal to 44 percent, almost the highest value in the Great Plains, strips definitely should be placed as nearly as possible at right angles to the prevailing wind erosion direction. But at La Junta, Colorado, with E_p equal to 17 percent, it does not matter much in which direction the wind barrier strips are placed.

At locations where E_p is greater than 25 percent, it is important to run the strips as nearly as possible at right angles to the prevailing wind erosion direction. The prevailing wind erosion direction that has E_p greater than 25 percent may be termed the significantly prevailing wind erosion direction. Using this as a criterion, figure 2 shows that in New Mexico, a part of western Texas, and eastern portions of Minnesota and Iowa the direction of wind barrier strips is of dubious importance. This does not mean that use of wind barrier strips is unimportant in those areas; it means only that their direction is relatively unimportant.

Summary

Throughout most of the Great Plains some definite prevailing wind erosion direction exists. This means that throughout most of the region it is definitely advantageous to lay field strips, to plant shelterbelts, to practice emergency erosion-reducing tillage, and to plant crops as nearly as possible at right angles to the prevailing wind erosion direction.

The prevailing wind erosion direction for the different parts of the Great Plains and the relative degree of certainty that the aforementioned practices should be carried out as nearly as possible at right angles to that direction have been determined (figure 2).

Information on the prevailing wind erosion direction should aid in determining the unsheltered distance, L, used to determine wind erodibility of farm fields and, conversely, to determine width of fields or field strips and intervals between wind barriers needed to control wind erosion at different locations in the Great Plains.

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