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PRINCIPLES OF WIND EROSION CONTROL

AND

THE WIND EROSION EQUATION

WITH

FACTOR VALUES FOR NORTH CAROLINA

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INTRODUCTION

Wind erosion is usually associated with great clouds of blowing soil and the "dust bowl" of the thirties. One would hardly expect damage from wind erosion in a state where the average annual rainfall amounts to about 48 inches, especially when 20 to 25 percent of the rain normally falls during the windiest months. No formal records have been kept which show the extent of wind erosion damage in North Carolina, but we know from experience that some wind erosion and crop damage may occur each spring.

Most of the wind damage in North Carolina takes place during February, March, and April when the winds of greatest magnitude occur. During this period, soils are loosened for spring planting and new crops are at their most tender stage. The worst problem by far, is in the eastern part of the state. Those counties with large, smooth, bare, sandy fields can expect the most damage.

Although some soil may be lost from fields, the greatest damage from blowing soil in North Carolina is likely to be the mutilation or destruction of tender young plants.

This handbook is provided for those who need to plan and apply wind erosion control systems. The information and procedures included are intended to provide guidance--not final answers--and should be used with discretion and good judgment.

BASIC MECHANICS OF WIND EROSION

Wind erosion begins on soils that are unsheltered, smooth, dry, bare, and most often, loose. Movement of soil particles starts when wind velocity nears a speed of 13 miles per hour, 1 foot above the ground. But obviously, the higher the wind speed, the greater the speed and volume of soil movement. Soil particles less than 0.1mm in diameter are carried in suspension and may be deposited many, many miles from their place of origin. These particles are most often particles of silt, clay, and organic matter stripped from the surface layers of the soil. Soil particles between 0.1 and 0.5mm in diameter move along in a bouncing, skipping motion called saltation. Larger blowing soil particles--those 0.5 to 1.0mm in diameter--move in a rolling motion over the soil surface. Their form of movement is known as "surface creep." Blowing soil particles spin at speeds estimated to be from 200 to 1,000 revolutions per second. As these particles move along, they strike other soil particles shattering and dislodging them and adding them to the volume of moving soil. This cumulative action is called avalanching and helps to explain why soil loss and damage to plants increase as the downwind distance from a wind barrier increases. However, once maximum soil flow is reached, additional downwind distance does not cause increased soil movement.

DAMAGES TO CROPS

Physical damage to crops is the result of the abrasive action of moving soil particles, burial of plants, removal of soil from the roots, and the desiccating and twisting effects of the wind.

Since tobacco, truck crops, and other high-value crops are often grown on the sandy soils in eastern North Carolina, they are frequently damaged by wind action. Other crops, usually lower in value, are frequently damaged but cause the landowners less concern.

Crop tolerances to soil blowing are often less than the allowable soil loss for the soil. When this is the case, it is necessary to design a wind erosion control system that will reduce soil blowing to a lesser amount than will normally cause crop damage. Estimated crop tolerances to soil blowing are shown in table 6.

Damage to crops usually occurs in the spring when plants are small and the soil surface is exposed to the wind. This critical period of exposure is relatively short, 80 percent or more of the soil blowing occurs at this time. Even though the soil loss is presently expressed in tons per acre per year, wind erosion control systems intended to protect crops must be designed to provide protection during the critical period. This means that the system may actually be necessary for a very short period, often as little as 2 or 3 weeks. Damage to a crop may occur in only a few minutes or as much as several hours. Systems are not usually designed to give complete protection to crops but should give adequate protection most of the time.

Relatively little information is available on the rate of soil loss that causes damage to crops. Based on the "Wind Erosion Equation", preliminary information gathered by the Soil Conservation Service indicates asparagus will be damaged on fields having a soil loss of 1.5 tons per acre per year; sweet potatoes, 1.4 tons per acre per year; table beets (1 inch high), 0.1 ton per acre per year; and winter spinach, 0.2 to 0.3 ton per acre per year. Therefore, it is necessary to design wind erosion control systems for such crops as: (1) asparagus and sweet potatoes, not to exceed 1 ton soil loss per acre per year; and (2) winter spinach and table beets, to permit no appreciable soil loss. Based on the tests conducted by the SCS, there should be little or no damage due to desiccation or twisting of plants by wind where systems are designed to reduce soil losses to a tolerable amount.

Not only will wind erosion control practices help prevent crop damage due to soil blowing, but there is evidence that such practices will result in increased yield. Bagley and Gowen report a 16 percent increase in yield of tomatoes and 37 percent increase in green snap beans.

PRINCIPLES OF WIND EROSION CONTROL SYSTEMS

A number of measures are effective in reducing the damaging effects of wind erosion. Many are also beneficial for soil improvements, water conservation, and water erosion control. Listed below is a brief description of these measures:

1. Cover Crops. An adequate cover of living vegetation during critical wind erosion periods will hold soil in place. The cover crop must be planted early enough and seeded heavily enough to make sufficient growth before blowing starts. While table 4 and field experience indicate that most damaging winds blow primarily from one direction, a damaging wind can come from more than one direction. Good cover will protect the land regardless of the direction the wind blows.

2. Crop residues. Soil covered by crop residue will also be protected against wind damage. Residues vary in their ability to protect soils by their kind, amount, and orientation. Chart 3, 4, and 6-9 converts these variables to a common denominator: namely, equivalents of flat small grain residue in pounds per acre. In general, the more residue on the ground, the greater the protection afforded. Small grain stubble is more effective per pound than corn or sorghum stalks, and corn and sorghum are more effective than cotton or soybean residues. Standing residues are about twice as effective as the same amount of residues flattened.

   Table 7 shows approximate amounts of residues produced by various crops. Table 8 show amounts of residue left after each tillage operation.

3. Conservation Tillage. The surface cover which is so effective in moisture conservation and water erosion control is effective against wind erosion. The greater the cover, generally, the greater the benefit.

   Even though a field is protected against wind erosion, an unsheltered distance may allow wind damage to young seedlings. While sand blowing may be the primary concern, just simply eliminating wind erosion with ground cover may not be sufficient.

4. Wind stripcropping. Growing wind-resisting crops in strips alternating with row crops and arranged at angles perpendicular to the erosive wind direction. This is very effective in reducing wind damage to crop seedlings and in reducing soil loss by wind.

5. Field Windbreak. A well-planned windbreak should probably be a part of most wind erosion control systems. Windbreaks may be used alone or in combination with other measures. The criteria for windbreaks is included in Field Office Technical Guides, Section IV.

Experience in windbreak establishment has shown a definite need for reducing competition from weeds, grass, and brush. More information on this aspect is found in the Technical Guide.

When new land is brought into cultivation, suitably spaced windbreaks of existing shrubs and trees should be left standing.

6. Emergency Tillage

Tillage to reduce damage by blowing winds is usually an emergency measure that is used when other and more effective practices have not or cannot be applied. It is often done after blowing starts and crops are already damaged.

Tillage is most effective when it is done at right angles to the wind and brings stable clods to the surface. Sometimes a high intensity rain will leave sand particles on the surface of the soil. These particles dry rapidly and will blow even when the topsoil is moist. Tillage can incorporate these particles into the soil and reduce damage.

Excessive tillage breaks down clods and loosens the soil and can result in more harm than good. Extra care must be used to prevent damage by water erosion when sloping fields are tilled for wind erosion control, and tillage for wind erosion control may not be practical in fields that are terraced and farmed on the contour. When a row crop is to follow the tillage, till either in the same direction as the rows or at right angles to them to reduce interference with the planter.

Chisels and lister-type implements are preferred for damage control tillage and tractor speeds should be kept to 3.5 to 4.0 miles per hour. Till only deep enough to bring stable soil to the surface or incorporate blowing sands.

7. Irrigation

The "C" or climatic factor in the Wind Erosion Equation relates to wind velocity and soil moisture. The first three principles of wind erosion control discussed above are based on effects on wind velocity, either directly or indirectly. There are few, if any, feasible practices we can apply on a field scale to increase the moisture content of the soil. Sprinkler irrigation is expensive, but may be justified to save a high-value crop. Generally, irrigating to control wind erosion is not practical.

THE WIND EROSION EQUATION

$$E = f(IKCLV)$$

This equation is used to estimate movement of soil by wind and to design management systems for croplands that will keep wind erosion damages within acceptable limits. Most of the earlier wind erosion research on which the equation is based was done in the vicinity of Garden City, Kansas, and many of the control practices now applied by using the equation were originally developed for the Great plains states. However, the principles used to estimate soil movement and to design controls can be applied anywhere blowing soil is a problem. The equation considers wind velocity, the differences in erodibility of soils, variations in climate, the roughness and smoothness of soil surfaces, the vegetative cover present, and the distance the wind blows across a field. These factors are indicated in the equation by symbols. The symbols are:

E "E" indicates potential soil movement due to wind erosion in tons per acre per year.

f This is a symbol indicating that "E" is a function of IKCLV. It is an expression of relationship only and has no numerical value in the equation.

I This is the factor that takes into account the fact that soils differ in their susceptability to wind erosion. Soil aggregates above 0.84mm in diameter are resistant to blowing and are generally classed as non-erosive. "I" values are expressed as the average annual soil loss (in tons per acre) of dry soil aggregates greater than 0.84mm in diameter occurring on a smooth, unsheltered, wide, bare field near Garden City, Kansas. An "I" value may be determined for an individual soil by sieving a sample taken from the top inch of soil with a U.S. Bureau of Standards No. 20 sieve and referring to a conversion table, but more often "I" values are assigned to soils on the basis of their texture classification. Table 2 places soils in wind erodibility groups (WEG) and lists their "I" value on the basis of their textural class, percent of dry aggregates less than 0.84mm in diameter, and other factors. The "I" values of all North Carolina soils are listed in Table 2. The "I" value of normally wet soils are based on their texture when they have been drained and are dry. Those soils in Table 2, such as marshes and tidelands that are rarely drained and are usually wet, are not assigned an "I" value.

K The "K" factor is called the soil ridge roughness factor. Its primary function is to evaluate the effect of ridges such as furrows and tool marks. Ridges and depressions formed by tillage absorb and deflect wind energy and trap-moving soil particles. At the same time, too much roughness can cause turbulence which accelerates particle movement.

The "K" value is based on a standard height-of-ridge to ridge-spacing ratio of 1:4. In the field, the "K" value is determined by reading directly from chart 1.

Ridges, as previously described, are most effective against wind erosion when they are at right angles to the prevailing wind erosion direction. They reduce wind velocities at or near the surface and also trap soil particles between the ridges. Unridged surfaces present a serious wind erosion hazard. Unridged surfaces do not materially reduce wind velocities at or near the surface but, instead, promote avalanching of soil flow.

C The climatic factor, "C," includes the effects of wind velocity and soil moisture on soil losses. The "C" factor for a given locality is determined by its average wind velocity and its precipitation-evaporation (P-E) index. Garden City, Kansas, with a "C" of 100 is the base locality for determining climatic factors. The "C" values of other areas are expressed as a percentage of that at Garden City and those for North Carolina can be determined readily from Table 3. The "C" values listed in Table 3 are monthly values for those months in which most wind damages occur.

L The unsheltered distance (in feet) <u>along the prevailing wind erosion direction</u> is "L." When a barrier such as a windbreak is present on the windward side of a field, the length of "L" is reduced by the distance protected by the barrier. The protected distance is equal to the height ("H") of the barrier times 10.[1/] For example, if a windbreak is 25 feet high, the distance it protects to the leeward is 10 x 25 or 250 feet, and 250 would be subtracted from the total distance downwind to determine "L." When the wind blows at an angle to a windbreak or barrier the downwind protected distance is less than when the wind strikes a barrrier at a right angle. A deviation from perpendicular of 22½° or less does not significantly reduce the protected distance, however. Angles of deviation greater than 22½° must be considered in determining the protected distance. For example: A field is located 300 feet downwind of a windbreak 30 feet high. The field is 500 feet wide and runs east-west. The windbreak is also aligned east-west, but the prevailing wind is from 215°. The angle of deviation is 35° (215° - 180° = 35°).

Refer to chart 2. Place a straight edge at 35 on scale C and at 300 ft. on scale A. On scale B, read 240 ft., which is the protected distance. Therefore, the field in question is not fully protected at the windward side.

To determine "L" for the above field, again refer to chart 2. Remember, the total distance across the opening is 800 ft. (500' + 300' = 800'). The windward 240 feet are protected, so the width of the area exposed to erosion is 800' - 240' = 560 ft. Place the straight edge at 35 on scale C and at 560 feet on scale B. Read 680 on side A. This is "L" for the above example.

V The "V" factor in the equation deals with the effects of vegetation. It includes the amount of residue, the kind of residue, and the orientation of the residue. The amount of air-dry residue per acre on the surface may be determined by any of several techniques. The finer vegetative material is, the greater its collective cross-sectional area and the more it reduces wind velocity and, consequently, soil movement. Orientation of residues refers not only to whether they are standing or flattened, but also to their height and uniformity of distribution. In the field, all residues are considered as equivalents of flattened small grain residues and converted to that basis by using charts 3, 4, and 6-9.

1/ The factor of 10 is normally used, but a dense windbreak may warrant the use of a higher value. Likewise, a thin windbreak may warrant the use of a lower value.

SOME ADDITIONAL WIND EROSION TERMS

Barrier

Any permanent or temporary obstruction to wind such as woodlands and windbreaks, a high roadfill, a field of tall grass or a strip of small grain in a field.

Sheltered Distance

The downwind distance from a barrier in which soil movement due to wind erosion is kept to an acceptable level.

Unsheltered Distance

The distance downwind from a barrier in which soil movement is excessive.

Perpendicular Distances

Distances in a field measured perpendicular to a boundary; usually the boundary at right angles to the prevailing wind, or the boundary on which a permanent barrier is located. Sheltered and unsheltered distances and strip widths may be converted to perpendicular distances when barriers are not at a right angle to the prevailing wind.

Prevailing Wind Direction

The direction <u>from</u> which a wind blows measured in degrees clockwise from north. Thus, a direction of 270 degrees would indicate a preponderance of winds blowing from west to east; and a direction of 45 degrees, winds predominantly from the northeast.

Angle of Deviation

The angle in degrees from which a wind direction deviates from perpendicular to a barrier or field border. Refer to Figure 1 for an illustration of the term.

Field Strip Width

This is the perpendicular distance between barriers in a field. The distance is based on "L." Computed strip widths are maximum widths, and in practice, a strip width is usually a multiple of a row or machinery widths which will keep soil movement within acceptable limits.

Excessive Soil Movement

Soil movement by wind is excessive when the rate of movement exceeds the "T" value of the soil or the tolerance of an individual crop. Refer to "T" value of the soil or the tolerance of an individual crop. Refer to the Field Office Technical Guide for "T" values and to Table 1 for crop tolerances.

EXAMPLES OF HOW TO USE THE WIND EROSION EQUATION

1. A field of wagram loamy sand in Wayne County is oriented in a NW/SE direction and is 1400 feet long and 600 feet wide. A good loblolly pine windbreak is along the windward side and stands 20 feet tall. The field was plowed and left smooth in mid-December. In late March, it was disked and planted to corn in 38 inch rows with ridges 2 inches high. By the end of April, the corn was tall enough to provide protection. It yielded 100 bushels per acre.

   a. Does the windbreak provide protection to this field?

   b. If the answer to a is no, then what would be the soil loss in tons/acre for the period of January through April?

   c. The following year this field will be flat-planted to soybean in 30-inch rows in early May following one disking of the corn residue with 20" blades. Is there enough corn residue to protect the soybeans? Assume no wind damage in June.

Procedure

a. No. The field is aligned along 135°. See in Table 4 that the wind direction is from 225°, which is perpendicular to the field and to the windbreak. Though this allows full effectiveness of the windbreak, its sheltered distance is 200 feet. See Figure 1. So, a 400 foot section of the width is not protected.

b. Determine the factors, IKCLV

I = 134 from Table 2.
K = 1 for January, February, March and 0.7 for April. From chart I.
C = 4, 3, 5, and 8, respectively for January, February, March, and April. From Table 3.
L = 400 ft. 600' wide minus 200' protected by the windbreak. From a above.
V = 0, as stated in the question.

Next, turn to the wind erosion tables for C=4, I=134, and K=1.0. Find 400 feet under the unsheltered distance column, read to the right under the "0" column the soil loss = 3.3 tons/ac./yr. To find the erosion for January, multiply 3.3 x .14 = 0.46 tons/ac. The .14 is the EWE from Table 5 for Goldsboro in January.

Now figure the loss for February. Turn to the wind erosion Tables for C=3, I=134, and K=1.0. Read 2.1 t/ac/yr under the 0 column for 400 feet. This would be the soil loss if it stayed February all year. To find the February loss, multiply 2.1 x 0.16 to get 0.34 tons/ac. The 0.16 comes from Table 5.

Next figure the loss for March. Use same procedure as above to get 3.8 t/ac/yr. x 0.20 = 0.76 t/ac. Then figure the loss for April. (Remember, the "K" changes to 0.7 this time) 3.2 t/ac/yr x .15 = 0.48 t/ac.

Finally, total the monthly losses:

January	= 0.46
February	= 0.34
March	= 0.76
April	= 0.48
TOTAL	2.04 Tons/ac.

c. First, figure the amount of residue produced by the corn crop. From Table 7, see that 56 lbs. of residue per bushel is produced. So the amount of residue is 5600 lbs. on the surface after harvest. But after one disking, only 60 % is left (Table 8) or 3360 lbs. Next, convert this to flat small grain residue. From chart 8, determine that 3360 lbs. of flat, randomly distributed corn residue converts to about 700 lbs. flat small grain residue.

Determine the factors I, K, C, L.

I = 134 from Table 2
K = 0.7 from Chart 1
C = 2 from Table 3
L = 400 ft. See a above.

Turn to the wind erosion tables. See that there is no table for C=2, so use 3. Under the "L" column for 400 ft. read to the right under the "V" column of 750; note that the soil loss is 0. So, the soybeans are adequately protected.

2. In Hoke County, a field of Norfolk loamy sand lies in a northeast-southwest direction and is 1200 ft. long by 800 ft. wide. A large block of cut-over woods lies one-half mile to the southwest. The re-growth is about 15 feet tall. Between the woods and the field in question lies a cultivated field and large field of coastal bermuda.

The field is turned and left smooth in early March. In early May, the field is planted to cotton on 2 inch-ridges in 42-inch rows.

a. What is the soil loss from wind erosion during the period of March-May?

b. Is the cotton adequately protected during May.

Procedure

a. Determine the factors, IKCLV

I = 134, from Table 2
K = 1.0 from chart 1. Note - even though there are shallow ridges, the row direction is parallel to the wind direction. See Table 4; wind direction is 225° which is from the SW. Therefore, use "K" of 1.0.
C = 5, 10, and 2 for March, April, and May respectively, from Table 3.