WIND EROSION

INTRODUCTION

Understanding the erosive forces of wind is essential to the correct use of the Wind Erosion Equation and interpretation of wind erosion data. NRCS predicts erosion rates, assesses potential damage, and plans control systems for wind erosion.

THE WIND EROSION PROBLEM

Wind is an erosive agent. It detaches and transports soil particles, sorts the finer from the coarser particles, and deposits them unevenly. Loss of the fertile topsoil in eroded areas reduces the rooting depth and, in many places, reduces crop yield. Abrasion by airborne soil particles damages plants and constructed structures. Drifting soil causes extensive damage also. Sand and dust in the air can harm animals, humans, and equipment.

Some wind erosion has always occurred as a natural land-forming process, but it has become detrimental as a result of human activities. This accelerated erosion is primarily caused by improper use and management of the land (Stallings 1951).

Few regions are entirely safe from wind erosion. Wherever the soil surface is loose and dry, vegetation is sparse or absent, and the wind sufficiently strong, erosion will occur unless control measures are applied (1957 Yearbook of Agriculture). Soil erosion by wind in North America is generally most severe in the Great Plains. The NRCS annual report of wind erosion conditions in the Great Plains shows that wind erosion damages from 1 million to more than 15 million acres annually, averaging more than 4 million acres per year in the 10-state area. USDA estimated that nearly 95 percent of the 6.5 million acres put out of production during the 1930's suffered serious wind erosion damage (Woodruff 1975). Other major regions subject to damaging wind erosion are the Columbia River plains; some parts of the Southwest and the Colorado Basin, the muck and sandy areas of the Great Lakes region, and the sands of the Gulf, Pacific, and Atlantic seaboards. In some areas, the primary problem caused by wind erosion is crop damage. Some crops are tolerant enough to withstand or recover from erosion damage. Other crops, including many vegetables and specialty crops, are especially vulnerable to wind erosion damage. Wind erosion may cause significant short-term economic loss in areas where erosion rates are below the soil loss tolerance (T) when the crops grown in that area are easily damaged by blowing soil (table 502-4).

THE WIND EROSION PROCESS

The wind erosion process is complex. It involves detaching, transporting, sorting, abrading, avalanching, and depositing of soil particles. Turbulent winds blowing over erodible soils cause wind erosion. Field conditions conducive to erosion include

- Lose, dry, and finely granulated soil;
- Sooth soil surface that has little or no vegetation present;
- Sufficiently large area susceptible to erosion; and
- Sufficient wind velocity to move soil.

Winds are considered erosive when they reach 13 miles per hour at 1 foot above the ground or about 18 miles per hour at a 30-foot height. This is commonly referred to as the threshold wind velocity (Lyles and Krauss 1971).

The wind transports primary soil particles or stable aggregates, or both, in three ways:

Saltation—Individual particles/aggregates ranging from 0.1 to 0.5 millimeter in diameter lift off the surface at a 50- to 90-degree angle and follow distinct trajectories under the influence of air resistance and gravity. The particles/aggregates return to the surface at impact angles of 6 to 14 degrees from the horizontal. Whether they rebound or embed themselves, they initiate movement of other particles/aggregates to create the avalanching effect. Saltating particles are the abrading bullets that remove the protective soil crusts and clods. Most saltation occurs within 12 inches above the soil surface and typically, the length of a saltating particle trajectory is about 10 times the height. From 50 to 80 percent of total transport is by saltation.

Suspensions—The finer particles, less than 0.1 millimeter in diameter, are dislodged from an eroding area by saltation and remain in the air mass for an extended period. Some suspension-sized particles or aggregates are present in the soil, but many are created by abrasion of larger aggregates during erosion. From 20 percent to more than 60 percent of an eroding soil may be carried in suspension, depending on soil texture. As a general rule, suspension increases downwind, and on long fields can easily exceed the amount of soil moved in saltation and creep.

Surface creep—Sand-sized particles/aggregates are set in motion by the impact of saltating particles. Under high winds, the whole soil surface appears to be creeping slowly forward as particles are pushed and rolled by the saltation flow. Surface creep may account for 7 to 25 percent of total transport (Chepil 1945 and Lyles 1980).

Saltation and creep particles are deposited in vegetated strips, ditches, or other areas sheltered from the wind, as long as these areas have the capacity to hold the sediment. Particles in suspension, however, may be carried a great distance. The rate of increase in soil flow along the wind direction varies directly with erodibility of field surfaces. The increase in erosion downwind (avalanching) is associated with the following processes:

- the increased concentration of saltating particles downwind increases the frequency of impacts and the degree of breakdown of clods and crusts, and
- the accumulation of erodible particles and breakdown of clods tends to produce a smoother (and more erodible) surface.

The distance required for soil flow to reach a maximum for a given soil is the same for any erosive wind. The more erodible the surface, the shorter the distance in which maximum flow is reached. Any factor that influences the erodibility of the surface influences the increase in soil flow.

How, why, and by whom wind erosion is estimated

Using the Wind Erosion Equation (WEQ), NRCS estimates erosion rates to

- Provide technical assistance to land users,
- Inventory natural resources, and
- Evaluate the effectiveness of conservation programs and conservation treatment applied to the land.

Wind erosion is difficult to measure. Wind moves across the land in a turbulent, erratic fashion. Soil may blow into, within, and out of a field in several directions in a single storm. The direction, velocity, duration, and variability of the wind all affect the erosion that occurs from a wind storm. Much of the soil eroding from a field bounces or creeps near the surface; however, some of the soil blown from a field may be high above the ground in a dust cloud by the time it reaches the edge of a field (Chepil 1963).

Methods of estimating wind erosion

No precise method of measuring wind erosion has been developed. However, various dust collectors, remote and in-place sensors, wind tunnels, sediment samplers, and microtopographic surveys before and after erosion have been used. Each method has its limitations. Research is continuing on new techniques and new devices, on modifications to older ones, and on means to measure wind erosion. Assigning numerical values to the site conditions that govern wind erosion and expressing their relationships mathematically can develop estimates of wind erosion. This is the basis of the current Wind Erosion Equation (WEQ). The WEQ considers soil erodibility, ridge and random roughness, climate, unsheltered distance, and vegetative cover.

THE WIND EROSION EQUATION

The Wind Erosion Equation (WEQ) erosion model is designed to predict long-term average annual soil losses from a field having specific characteristics. With appropriate selection of factor values, the equation will estimate average annual erosion or erosion for specific time-periods.

DEVELOPMENT OF THE WIND EROSION EQUATION

Drought and wind erosion during the l9th century caused wind erosion to be recognized as an important geologic phenomenon. By the late 1930's, systematic and scientific research into wind erosion was being pioneered in California, South Dakota, Texas, and in Canada and England. This research produced information on the mechanics of soil transport by wind, the influence of cultural treatment on rates of movement, and the influence of windbreaks on windflow patterns. The publication, The Physics of Blown Sand and Desert Dunes, (Bagnold 1941), is considered a classic by wind erosion researchers. In 1947, USDA began the Wind Erosion Research Program at Manhattan, Kansas, in cooperation with Kansas State University. That program was started under the leadership of Austin W. Zingg, who was soon joined by W.S. Chepil, a pioneer in wind erosion research in Canada. The research project's primary purposes were to study the mechanics of wind erosion, delineate major influences on that erosion, and devise and develop methods to control it. By 1954, Chepil and his coworkers began to publish results of their research in the form of wind erosion prediction equations (Chepil 1954; Chepil 1957; Chepil et al. 1955; Woodruff and Chepil 1956). In 1959, Chepil released an equation:

E = IRKFBWD, where:

E = quantity of erosion
I = soil cloddiness
R = residue
K = roughness
F = soil abradability
B = wind barrier
W = width of field

D = wind direction

Wind velocity at geographic locations was not addressed in this equation (Chepil 1959). In 1962, Chepil's group released the equation:

E= ∫(ACKLV)

where:

A = percentage of soil fractions greater than 0.84 millimeter.

Factors C, K, L, and V were the same as in the present equation although they were not handled the same (Chepil 1962). A C-factor map for the western half of the United States was also published in 1962 (Chepil et al. 1962).

In 1963, the current form of the equation, E =f(IKCLV) was first released (Chepil 1963). In 1965, the concept of preponderance in assessing wind erosion forces was introduced. See 502.34 for details on preponderance (Skidmore 1965 and Skidmore and Woodruff 1968).

In 1968, monthly climatic factors were published (Woodruff and Armbrust 1968). These are no longer used by NRCS. Instead, NRCS adopted a proposal for computing soil erosion by periods using wind energy distribution that was published in 1980 (Bondy et al. 1980). (See 502.24.) In 1981, the Wind Erosion Research Unit provided NRCS with data on the distribution of erosive wind energy for the United States and in 1982 provided updated annual C factors.

Although the present equation has significant limitations, it is the best tool currently available for making reasonable estimates of wind erosion. Currently, research and development of improved procedures for estimating wind erosion are underway.

The present Wind Erosion Equation is expressed as:

E = ∫(IKCLV), where:

E = estimated average annual soil loss in tons per acre per year
∫ = indicates relationships that are not straight-line mathematical calculations
I = soil erodibility index
K = soil surface roughness factor
C = climatic factor
L = the unsheltered distance

V = the vegetative cover factor

The I factor, expressed as the average annual soil loss in tons per acre per year from a field area, accounts for the inherent soil properties affecting erodibility. These properties include texture, organic matter, and calcium carbonate percentage. I is the potential annual wind erosion for a given soil under a given set of field conditions. The given set of field conditions for which I is referenced is that of an isolated, unsheltered, wide, bare, smooth, level, loose, and noncrusted soil surface, and at a location where the climatic factor (C) is equal to 100.

The K factor is a measure of the effect of ridges and cloddiness made by tillage and planting implements. It is expressed as a decimal from 0.1 to 1.0.

The C factor for any given locality characterizes climatic erosivity, specifically wind speed and surface soil moisture. This factor is expressed as a percentage of the C factor for Garden City, Kansas, which has a value of 100. The L factor considers the unprotected distance along the prevailing erosive wind direction across the area to be evaluated and the preponderance of the prevailing erosive winds. The V factor considers the kind, amount, and orientation of vegetation on the surface. The vegetative cover is expressed in pounds per acre of a flat small-grain residue equivalent.

LIMITATIONS OF THE EQUATION

When the unsheltered distance, L, *is sufficiently long, the transport capacity of the wind for saltation and creep is reached*. If the wind is moving all the soil it can carry across a given surface, the inflow into a downwind area of the field is equal to the outflow from that same area of the field, for saltation and creep. The net soil loss from this specific area of the field is then only the suspension component. This does not imply a reduced soil erosion problem because, theoretically, there is still the estimated amount of soil loss in creep, saltation, and suspension leaving the downwind edge of the field.

Surface armoring by non-erodible gravel is not usually addressed in the I factor.

The equation does not account for snow cover or seasonal changes in soil erodibility. The equation does not estimate erosion from single storm events.

ALTERNATIVE PROCEDURES FOR USING THE WEQ

The WEQ Critical Period Procedure is based on use of the Wind Erosion Equation as described by Woodruff and Siddoway in 1965 (Woodruff and Siddoway 1965). The conditions during the critical wind erosion period are used to derive the estimate of annual wind erosion.

- The Critical Wind Erosion Period is described as the period of the year when the greatest amount of wind erosion can be expected to occur from a field under an identified management system. It is the period when vegetative cover, soil surface conditions, and expected erosive winds result in the greatest potential for wind erosion.
- Erosion estimates developed using the critical period procedure are made using a single set of factor values (IKCL & V) in the equation to describe the critical wind erosion period conditions.

The critical period procedure is currently used for resource inventories. NRCS usually provides specific instructions on developing wind erosion estimates for resource inventories. The WEQ Management Period Procedure was published by Bondy, Lyles, and Hayes in 1980. It solves the equation for situations where site conditions have significant variation during the year or planning period where the soil is exposed to soil erosion for short periods, and where crop damage is the foremost conservation concern, rather than the extent of soil loss. The management period procedure is described as being more responsive to changing conditions throughout the cropping year but is not considered more accurate than the critical period procedure.

Comparisons should not be made between the soil erosion predictions made by the management period procedure and the critical period procedure. In other words, where a conservation system has been determined to be acceptable by the management period procedure and placed in a conservation plan or the FOTG, then only the management period procedure will be used to determine if other conservation systems, planned or applied, provide equivalent treatment.