Soil erosion by wind

Abstract

In the arid and semiarid regions of the United States, large areas are affected by wind erosion. The Great Plains region, an area especially subject to soil movement by wind, represents about 20 percent of the total land area in the United States. Many humid regions are also damaged by wind erosion. The areas most subject to damage are the sandy soils along streams, lakes, and coastal plains and organic soils. Peats and mucks constitute about 10 million ha located in 34 states.

Wind erosion not only removes soil, but also damages crops, fences, buildings, and highways. Fine soil particles are lost along with nutrients, which can result in reduced crop yields. Eroded sediment particles are a nuisance for many people and can adversely affect the health of some individuals. There are also circumstances where eroded dust can obscure visibility. Such conditions can lead to fatal traffic accidents. For example, in 1991, 104 vehicles were involved in an accident on Interstate 5 in California, resulting in 15 deaths and 150 injuries.

Dust particles can travel far, even crossing oceans. It was the deposition of dust in Washington, D.C., from wind erosion in the Great Plains in the 1930s that resulted in the U.S. government establishing the Soil Conservation Service. Figure 20-1 shows the distribution of wind erosion hazard in the states west of the Mississippi River.

20.1 Air Quality

A major issue related to wind erosion is air quality (Saxton et al., 2000). The U.S. Environmental Protection Agency (EPA, 2003) has determined that particulate matter in the air can be detrimental to human health. Airborne particles are particularly dangerous for the elderly, individuals with cardiopulmonary diseases, and children. These particulates fall into two classes, coarse, less than 10 microns in diameter (PM-10), and fine, less than 2.5 microns (PM-2.5). The particles can come from a variety of sources. Fine particles are generally associated with automotive and other smoke emissions. Coarse particles are generated from unpaved roads, materials handling and grinding, and agriculture. Generally, agriculture is not a major contributor to poor air quality, but there are some areas, during some critical periods of the year, where this is not the case. Dust from wind erosion may further degrade air quality in

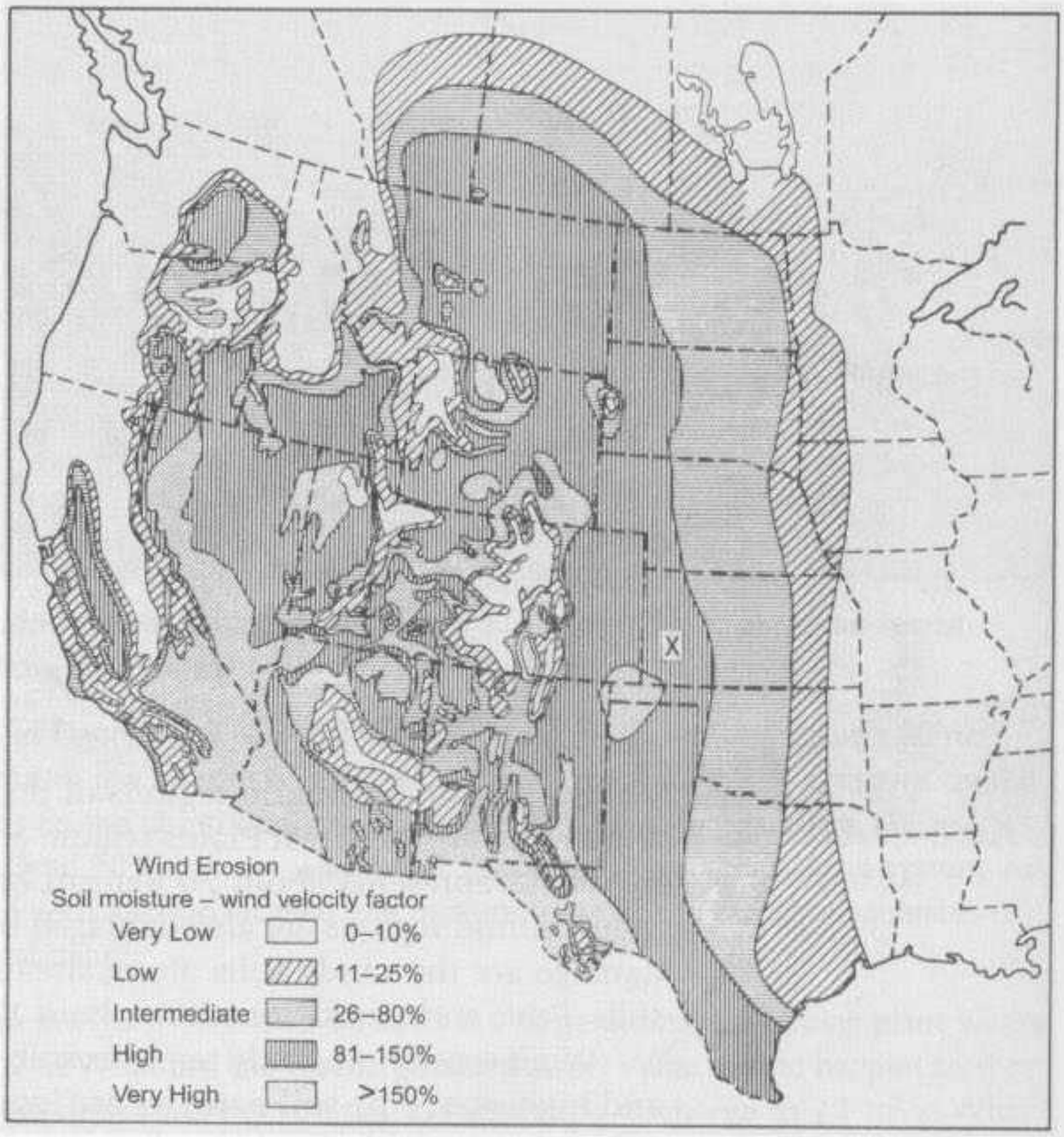


Figure 20–1
Relative potential soil loss by wind for the western United States and southern Canada as a percentage of that in the vicinity of Garden City, Kansas, marked by X. (Chepil et al., 1962)

some regions with air quality problems from other sources, such as the industrial areas around the Great Lakes. Readers are encouraged to determine the degree of local concern about airborne particles due to wind erosion.

The 1997 EPA standards for particles set the limit for PM-2.5 at 15 μg particulate matter per cubic meter of air annually, and 65 $\mu g\ m^{-3}$daily. The PM-10 values are set at 50 $\mu g\ m^{-3}$ annually and 150 $\mu g\ m^{-3}$ as a daily standard.

20.2 Wind and Water Erosion Processes

The physical processes causing particle detachment and transport in wind erosion are similar to the processes involved in rill and channel erosion by water. With wind, the fluid carrying the particles is a low-density gas, whereas in water it is a higher-density liquid. The density of the soil particles and the fluid, and the velocity and shear of the fluid on the particles affect the rate of particle detachment and subsequent transport. With both wind and water, the shear of the fluid varies greatly in time and location during an erosion event. Higher detachment rates result from pulses of high fluid shear, and deposition occurs when there is a drop in the shear further downstream or later in time. In both wind and water, small particles are more easily transported, particularly in suspension, whereas coarser, noncohesive particles tend to be more easily detached. Soil aggregates with lower densities are more likely to be transported than soil particles with higher densities. With wind erosion, moist soil has greater cohesion than dry soil and is less easily detached,

whereas with streambank and other mass erosion, saturated soils have less cohesion than unsaturated soils and are more likely to fail.

20.3 Types of Soil Movement

Saltation, suspension, and surface creep are the three types of soil movement with both wind erosion and channel and rill erosion with water (Figure 20-2). Saltation is the process where fine particles (0.1 to 0.5 mm in diameter) are lifted from the surface and follow distinct trajectories under the influence of air resistance and gravity. When the particles return to the surface, they may rebound or become embedded when impacting the surface, but in either case they initiate movement of other particles to create an "avalanching" effect of additional soil movement. Most saltation occurs within 0.3 m of the surface. Saltation accounts for 55 to 72 percent of particle movement during wind erosion events. Suspended particles (0.02 to 0.1 mm in diameter) are dislodged by saltating particles and represent 3 to 10 percent of eroding particles. The smaller suspended particles may remain aloft for an extended period, traveling hundreds of kilometers. These suspended particles may become nuclei for raindrop formation. Sand-sized particles or aggregates (0.5 to 2 mm in diameter) are set in motion by the impact of saltating particles, and tend to roll or creep along the surface. Creep accounts for 7 to 25 percent of the soil movement.

20.4 Mechanics of Wind Erosion

For a precise understanding of the mechanics of wind erosion, an analysis must be made of the interactions among the climate, the soil, vegetation, and the length of exposed soil. Wind erosion may be divided into the three processes: (1) initiation of movement, (2) transportation, and (3) deposition.

Initiation of Movement. Soil movement is initiated from air turbulence and velocity. The fluid threshold velocity is defined as the minimum velocity required to produce soil movement by direct action of the wind, and the impact threshold velocity is the minimum velocity necessary to initiate movement from the impact of soil particles carried by saltation. The wind is always turbulent except near the

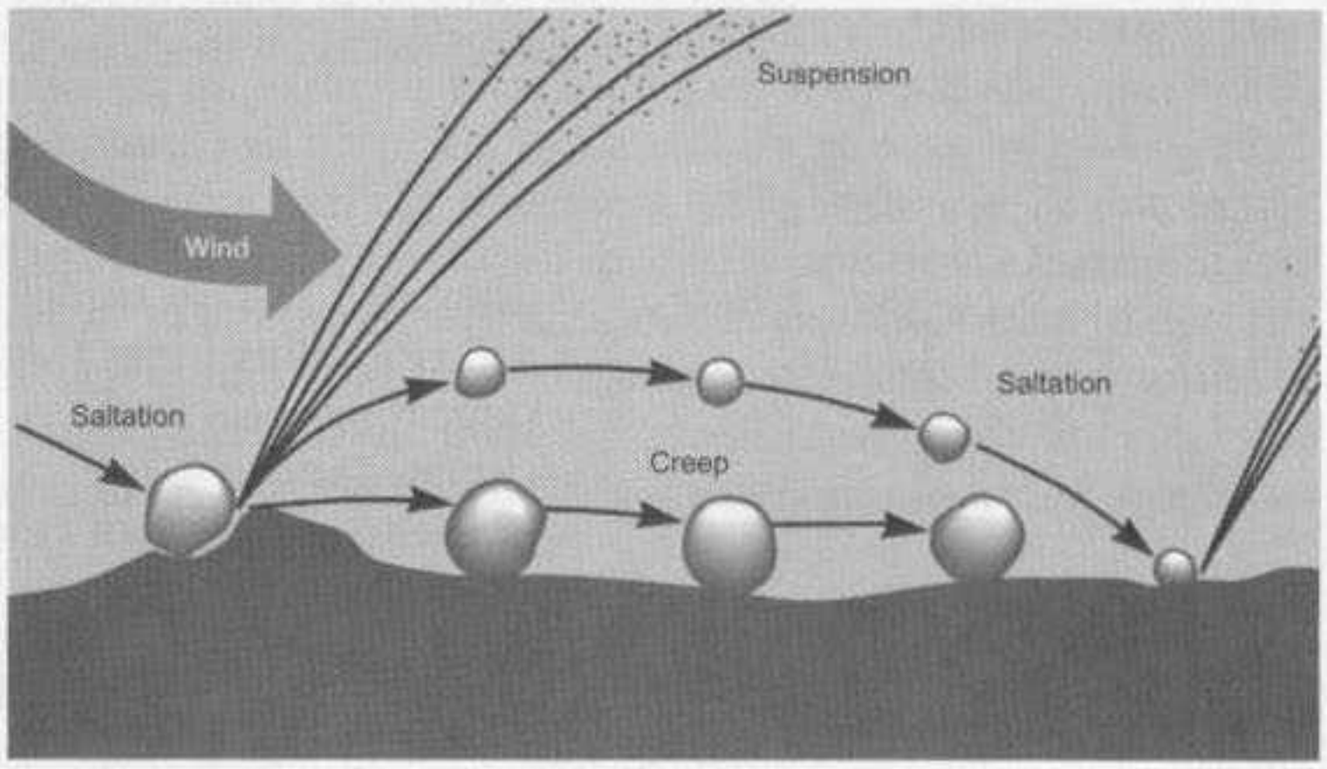


Figure 20–2
Main processes of soil movement by wind. (ARS, 2003)

surface and at low velocities (less than about 1 m/s). Wind speeds of 5 m/s or less at 0.3-m height are usually considered nonerosive for mineral soils.

Transportation. The quantity of soil moved is influenced by the aggregate size, texture, wind velocity, and distance across the eroding area. Winds, being variable in velocity and direction, produce gusts with eddies and cross currents that lift and transport soil. The quantity of soil moved varies as the cube of the excess wind velocity above the constant threshold velocity, the square root of the soil aggregate diameter, and the gradation of the soil.

The rate of soil movement increases with the distance from the windward edge of the field or eroded area. Fine particles drift and accumulate on the leeward side of the area or pile up in dunes. Increased rates of soil movement with distance from the windward edge of the area subject to erosion are the result of increasing amounts of erosive particles, thus causing greater abrasion and a gradual decrease in surface roughness.

The atmosphere has a tremendous capacity for transporting sediment in suspension, particularly those soil fractions less than 0.1 mm in diameter. It is estimated that the potential carrying capacity per cubic kilometer of the atmosphere is many tonnes of soil, depending on the wind velocity. For example, a dust storm originating in the Texas Panhandle deposited over 200 kg/ha in Iowa in 1937.

Deposition. Deposition of windborne sediment occurs when the gravitational force is greater than the forces holding the particles in the air. The process generally occurs when there is a decrease in wind velocity caused by vegetation or other physical barriers, such as ditches, vegetation, and snow fences. Raindrops may also remove dust from the air.

20.5 Estimating Wind Erosion

The most widely used method for estimating wind erosion is the Wind Erosion Equation method (WEQ) (NRCS, 2002). A computer model is now available, the Wind Erosion Prediction System (WEPS) model, that will eventually replace the WEQ method (ARS, 2003). A solution using the WEQ method is presented since it can be solved without the need for a computer. A spreadsheet solution to the WEQ, including a soil and climate database, is available (NRCS, 2003). Readers are encouraged to download the latest version of the WEPS computer model to compare to the predictions from examples and problems presented in this chapter. The WEQ method is presented as an interaction among five factors.

$$E = f(I,K,C,L,V) \qquad \textbf{20.1}$$

where E = estimated average annual soil loss (Mg ha^{-1} y^{-1}),
I = soil erodibility index (Mg ha^{-1} y^{-1}),
K = ridge roughness factor,
C = climate factor,
L = unsheltered length of eroding field (m),
V = vegetative cover factor.

Erodibility Index, *I*. The above factors are not independent, but must be combined in a set of interacting equations to estimate wind erosion. The wind

TABLE 20–1 Typical Wind Erodibility Indices for Different Soil Textures

Predominant Soil Texture and Soil Erodibility Index	*Soil Erodibility Index I (Mg/ha-year)*
Loamy sands and sapric organic material[a]	360–700
Loamy sands	300
Sandy loams	200
Clays and clay loams	200
Calcareous loams	200
Noncalcareous loams, silt loam <20% clay, and hemic organic soils	125
Noncalcareous loams and silt loams >20% clay	100
Silt, noncalcareous silty clay loam and fibric organic soils	85
Wet or rocky soils not susceptible to erosion	—

[a] The *I* factors for Group 1 vary from 360 for coarse sands to 700 for very fine sands. Use 500 for an average. Based on NRCS (2002).

erodibility, *I*, is a function of the soil aggregates greater than 0.84 mm in diameter. The following regression equation was developed from estimates of *I* given in Woodruff & Siddoway (1965).

$$I = 525\, e^{(-0.04F)} \qquad \textbf{20.2}$$

where *I* is the wind erodibility, *e* is the natural logarithm base (2.718), and *F* is the percentage of dry soil fraction greater than 0.84 mm. The fraction of dry soil can vary during the season and can also be altered with changes in soil water content and organic matter. Table 20-1 summarizes typical soil wind erodibility values for different textures of soil.

Surface crusting caused by wetting and drying may reduce erosion on many soils, but is not considered in the WEQ method. Irrigation can also decrease erodibility, and suggested values for the *I* factor with irrigation are available (NRCS, 2002). The WEPS model accounts for crusting effects and the interaction between time of crusting and occurrence of wind erosion events (Hagen, 1991).

Roughness Factor, *K*. The roughness factor, *K*, is a measure of the effect of ridges made by tillage and planting implements on erosion rate. Ridges absorb and deflect wind energy and trap moving soil particles. Too much roughness, however, causes turbulence which may accelerate particle movement. Roughness can be due to natural undulations and the presence of knolls on the landscape where increased erosion has been observed, or to temporary ridges from tillage, which tend to decrease erosion rates. Table 20-2 provides adjustment factors that should be multiplied by the erodibility index *I* to account for the increased erosion on windward sides and tops of knolls. To estimate *K*, it is necessary to first estimate the ridge roughness from the equation

$$K_r = 4\frac{h^2}{d} \qquad \textbf{20.3}$$

TABLE 20–2 Knoll Erodibility Adjustment Factors

Slope Change in Prevailing Wind Erosion Direction (%)	*Knoll Adjustment to I (factor)*	*Increase at Crest Area Where Erosion Is Most Severe (factor)*
3	1.3	1.5
4	1.6	1.9
5	1.9	2.5
6	2.3	3.2
8	3.0	4.8
10	3.6	6.8

Source: NRCS (2002).

where K_r = ridge roughness (mm),
h = ridge height (mm),
d = ridge spacing (mm).

From the ridge roughness K_r, the roughness factor K can be calculated by the regression relationship derived from Woodruff & Siddoway (1965).

$$K = 0.34 + \frac{12}{K_r + 18} + 6.2 \times 10^{-6} K_r^2 \qquad \textbf{20.4}$$

If the dominant wind direction is other than normal to the direction of the ridges, then the value of K is reduced, depending on the direction of the wind, and the value of I (NRCS, 2002).

Climate Factor, *C*. The climate factor is an index of climate erosivity, which includes the wind speed and the soil content at the surface. It is expressed as a fraction of the C factor for Garden City, Kansas. Figure 20-1 shows the distribution of C factors for the western United States. An interactive map to find C factors for the United States can be found online at http://nm6.ftw.nrcs.usda.gov/website/. Readers are encouraged to check with local agencies or state websites for local C factors. Methods to calculate the C factor considering wind speed, precipitation, and evapotranspiration are presented in NRCS (2002).

Unsheltered Distance, *L*. The L factor represents the unsheltered distance in meters along the prevailing wind erosion direction for the field or area to be evaluated. This distance is the length from a sheltered edge of a field, parallel to the direction of the prevailing wind, to the end of the unsheltered field.

Vegetative Cover Factor, *V*. The effect of vegetative cover in the wind erosion equation is expressed by relating the kind, amount, and orientation of vegetative material to its equivalent of small-grain residue. The small-grain equivalent (Skidmore, 1994) can be calculated from the relationship

$$SG = a\, R_w^b \qquad \textbf{20.5}$$

where SG = small-grain equivalent (kg/ha),
a, b = crop constants from Table 20-3,
R_w = quantity of residue to be converted to small-grain equivalent (kg/ha).

Where more than one crop is involved, such as growing a crop of sorghum with wheat residue, a weighted average of the coefficients is necessary so that

$$SG = a_1^{p_1} a_2^{p_2} (R_{w_1} + R_{w_2})^{b_1 p_1 + b_2 p_2} \quad \textbf{20.6}$$

Where p_1 and p_2 are the fractions of crop residue in each category (Skidmore, 1994). From the small-grain equivalent, the vegetative cover factor V (Mg/ha) can be calculated using

$$V = 2.533 \times 10^{-4} (SG)^{1.363} \quad \textbf{20.7}$$

Predicting Erosion. The prediction method presented here is based on Skidmore (1994) and is similar to that presented in the *NRCS National Agronomy Manual* (NRCS, 2002). To estimate annual erosion, the climate erosivity is estimated from Figure 20-1 or from a climate calculation. The soil erodibility index is determined from Equation 20.2 or Table 20-1. The effect of knolls may be included by multiplying I by the appropriate factor from Table 20-2. The ridge roughness factor is calculated from Equations 20.3 and 20.4. The estimated annual wind erosion can then be calculated by the following steps:

(1) The initial estimate of wind erosion E_1 is I, found from Equation 20.2 or Table 20-1 in Mg ha^{-1} y^{-1}

$$E_1 = I \quad \textbf{20.8}$$

(2) Calculate E_2 from Equation 20.8 and the soil and surface properties contained in Equation 20.4.

$$E_2 = I\,K \quad \textbf{20.9}$$

(3) Calculate E_3 by including the climate factor C presented in Figure 20-1 or from local information.

$$E_3 = I\,K\,C \quad \textbf{20.10}$$

(4) Calculate the maximum field length L_o for reducing the wind erosion estimate.

$$L_o\,(\text{m}) = 1.56 \times 10^6 (E_2)^{-1.26} e^{(-0.00156 E_2)} \quad \textbf{20.11}$$

(5) Calculate the field length factor WF

$$WF(\text{Mg ha}^{-1}\,\text{y}^{-1}) = E_2 \times \left(1.0 - 1.2\left[\frac{L}{L_o}\right]^{-0.383}\right) e^{L/L_o} \quad \textbf{20.12}$$

where L = unsheltered distance (m).

(6) Calculate E_4 by combining the interaction of surface, soil, climate, and length effects.

$$E_4\,(\text{Mg ha}^{-1}\,\text{y}^{-1}) = (WF^{0.348} + E_3^{\,0.348} - E_2^{\,0.348})^{2.87} \quad \textbf{20.13}$$

TABLE 20–3 Crop Residue Coefficients for Predicting Small-Grain Residue Equivalent (*SG*) (Kg/ha) from Crop Residues

Crop Residue	*Height (mm)*	*Length (mm)*	*Row Spacing (mm)*	*Orientation to Wind*	*Value a*	*Value b*
Surface Orientation: Standing						
Winter wheat	250	—	250	Normal	4.306	0.970
Rape	250	—	250	Normal	0.103	1.400
Cotton	340	—	750	Normal	0.188	1.145
Sunflowers	430	—	750	Normal	0.021	1.342
Forage sorghum	150	—	750	Normal	0.353	1.124
Silage corn	150	—	750	Normal	0.229	1.135
Surface orientation: Flat–random						
Winter wheat	—	250	—	—	7.279	0.782
Soybeans	—	250	—	—	0.167	1.173
Rape	—	250	—	—	0.064	1.294
Cotton	—	250	—	—	0.077	1.168
Sunflowers	—	430	—	—	0.011	1.368
Soybeans						
1/10 standing	60	—	750	Normal	0.016	1.553
9/10 flat–random	—	250	—	—	0.167	1.170
Ungrazed Rangeland						
Blue grama	300	—	—	—	0.60	1.39
Buffalograss	100	—	—	—	1.40	1.44
Properly Grazed Rangeland						
Big bluestem	150	—	—	—	0.22	1.34
Blue grama	50	—	—	—	1.60	1.08
Buffalograss	50	—	—	—	3.08	1.18
Little bluestem	100	—	—	—	0.19	1.37
Switchgrass	150	—	—	—	0.47	1.40
Western wheatgrass	100	—	—	—	1.54	1.17
Overgrazed Rangeland						
Big bluestem	25	—	—	—	4.12	0.92
Blue grama	25	—	—	—	3.06	1.14
Buffalograss	15	—	—	—	2.45	1.40
Little bluestem	30	—	—	—	0.52	1.26
Switchgrass	25	—	—	—	1.80	1.12
Western wheatgrass	25	—	—	—	3.93	1.07

Source: Skidmore (1994).

(7) Calculate the effects of vegetation through two factors based on the vegetative cover factor *V*.

$$a = e^{(-7.59V - 4.47\times10^{-1}V^2 + 2.95\times10^{-4}V^3)} \quad \textbf{20.14}$$

$$b = 1.0 + 8.93 \times 10^{-2}V + 8.51 \times 10^{-3}V^2 - 1.5 \times 10^{-5}V^3 \quad \textbf{20.15}$$

(8) Incorporate the vegetation factors into the erosion estimate.

$$E_5(\text{Mg ha}^{-1}\text{y}^{-1}) = a\,E_4^b \quad \textbf{20.16}$$

When working with these equations, it will become apparent that for high values of field length the effect of field length becomes minimal. This is because these equations predict erosion mainly by saltation and creep processes, and these processes are limited by the transport capacity of the site. To include suspended material, the reader should use the WEPS model, which allows for increased erosion at longer lengths as detached material becomes suspended at greater heights in the atmosphere (ARS, 2003) and is not limited by surface wind alone to detach and transport sediment.

Example 20.1

A field is 800 m long in central Kansas (from Figure 20-1 $C = 0.8$). From a sieve analysis, it is determined that the soil has 25 percent nonerodible clods (>0.84 mm). Several knolls with 3 percent slopes are in the field. A crop of forage sorghum was grown in 750-mm rows, and 500 kg/ha of 150-mm-tall stubble remains standing in the field. The ridge roughness is 100 mm. What is the estimated annual soil loss due to wind erosion on this field?

Solution. The soil loss is calculated following the steps described above.

(1) Calculate *I* from the clod content (Equation 20.2).

$$I = 525 \times e^{(-0.04\times2.5)} = 193\ \text{Mg ha}^{-1}\text{y}^{-1}$$

(2) Calculate the effect of the 3 percent knolls from Table 20-2.

$$I = 193 \times 1.3 = 251\ \text{Mg ha}^{-1}\text{y}^{-1}$$

(3) Calculate the roughness factor for a ridge roughness of 100 mm (Equation 20.4).

$$K = 0.34 + \frac{12}{100 + 18} + 6.2 \times 10^{-6} \times 100^2 = 0.5$$

(4) Calculate E_2 from Equation 20.9.

$$E_2 = 251 \times 0.5 = 126\ \text{Mg ha}^{-1}\text{y}^{-1}$$

(5) Calculate E_3 from Equation 20.10 with $C = 0.80$.

$$E_3 = 193 \times 0.5 \times 0.8 = 100\ \text{Mg ha}^{-1}\text{y}^{-1}$$

(6) Calculate L_o from Equation 20.11.

$$L_o = 1.56 \times 10^6 (126)^{-1.26} e^{(-.00156 \times 126)} = 2877 \text{ m}$$

(7) Calculate *WF* from Equation 20.12.

$$WF = 126 \times \left(1.0 - 1.2\left[\frac{800}{2877}\right]^{-0.383}\right) e^{800/2877} = 102$$

(8) Calculate E_4 from Equation 20.13.

$$E_4 = (102^{0.348} + 100^{0.348} - 126^{0.348})^{2.87} = 79.4 \text{ Mg ha}^{-1} \text{ y}^{-1}$$

(9) Calculate the small-grain equivalent from Equation 20.5. From Table 20-3, $a = 0.353$ and $b = 1.124$.

$$SG = 0.353 \times 500^{1.124} = 381 \text{ kg/ha}$$

(10) Calculate the vegetative cover factor from Equation 20.7.

$$V = 2.533 \times 10^{-4} (381)^{1.363} = 0.836$$

(11) Calculate vegetation factors from Equation 20.14 and 20.15.

$$a = e^{(-7.59 \times .836 - 4.47 \times 10^{-1} \times 0.836^2 + 2.95 \times 10^{-4} \times 0.836^3)} = 0.513$$

$b = 1.0 + 8.93 \times 10^{-2} \times 0.836 + 8.51 \times 10^{-3} \times 0.836^2 - 1.5 \times 10^{-5} \times 0.836^3 = 1.08$

(12) Incorporate vegetation factors into erosion prediction with Equation 20.16.

$$E_5 = 0.513 \times 79.4^{1.08} = 57.9 \text{ Mg ha}^{-1} \text{ y}^{-1}$$

Thus, the estimated soil loss is 57.9 Mg ha^{-1} y^{-1}.

If the above loss is unacceptable, the loss can be reduced by reducing the length of the field with respect to the prevailing wind direction, by increasing the residue cover, or possibly by increasing the clod content of the soil surface through tillage.

Control Practices

20.6 Cultivated Crops

In general, close-growing crops are more effective for erosion control than are row crops. The effectiveness of crops is dependent on stage of growth, density of cover,

row direction, width of rows, kind of crop, and climatic conditions. Pasture or meadow may accumulate soil from neighboring cultivated fields if there are good grazing management practices. Good management grazing practices such as rotation grazing are important to minimize erosion, because sparse rangelands are also susceptible to wind erosion, as can be seen from the vegetation coefficients for rangeland in Table 20-3.

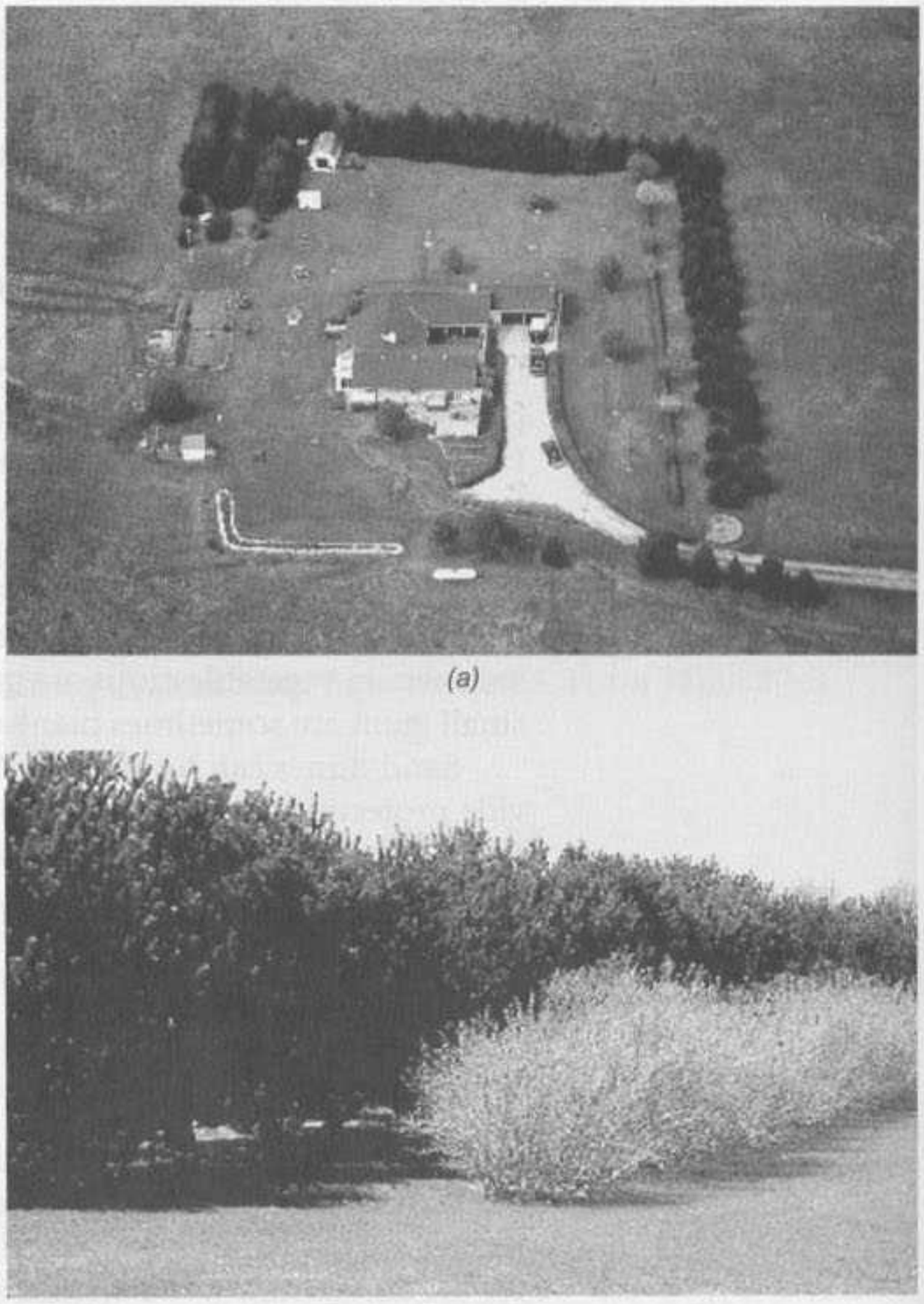
Tillage and planting normal to the prevailing winds will reduce the risk of wind erosion. A crop rotation that will maintain soil structure and conserve water should be followed. Crops adapted to soil and climatic conditions and providing as much protection against erosion as practical are recommended. For instance, in the Great Plains region forage sorghum and Sudan grass are resistant to drought and are effective in preventing wind erosion. In more humid regions, stubble mulch farming and cover crops between row crops can reduce wind erosion between cropping seasons. In some dry regions, emergency crops with low water requirements may be established on summer fallow land before seasons of high-intensity winds. In muck soils where vegetable crops are grown, miniature windbreaks consisting of rows of small grain are sometimes planted.

Sand dunes can be stabilized by first planting drought-resistant grasses to provide protection until appropriate shrubs or trees can be established. The vegetation should have the ability to grow in the open on sandy soil, be wind resistant, and have a long life. Vegetation should also provide a dense cover during critical seasons, provide as uniform an obstruction to the wind as possible, reduce the surface wind velocity, and form an abundance of crop residue.

20.7 Windbreaks and Shelterbelts

Windbreaks are generally associated with mechanical or vegetative barriers for buildings, gardens, orchards, and feed lots (Figure 20-3). A shelterbelt is a longer barrier than a windbreak, usually consisting of shrubs and trees, and is intended for the conservation of soil and water and for the protection of field crops. About 450 000 km of windbreaks and shelterbelts have been planted in the United States since the middle of the 1800s. Windbreaks and shelterbelts are valuable for wind erosion control, reduce heating and cooling costs, increase livestock gains, reduce evaporation, reduce crop damage from hot winds, catch snow during the winter months, provide better fruiting in orchards, and make spraying of orchards for insect control more effective. Windbreaks may also improve offsite water quality, or provide wildlife habitat.

The relative wind velocity near a windbreak is shown in Figure 20-4. Depending on the effectiveness of the windbreak, reduction in wind velocity can occur for a distance up to 20 times the height of the windbreak. Shelterbelts should be moderately dense from ground level to treetops if they are to be effective in filtering the wind and lifting it from the surface. Long shelterbelts are more effective than short ones. An opening or break in an otherwise continuous belt will reduce the effectiveness. Roads through shelterbelts should be avoided, and, when essential, they should cross the belt at an angle or should be curved. In establishing the direction of shelterbelts, records of wind direction and velocity, particularly during vulnerable seasons, should be considered, and the barrier should be oriented as nearly as possible at right angles to the prevailing direction of winds. Such information for many locations in the United States is available from NRCS (2003).



(a)

(b)

Figure 20–3
Typical shelterbelts. (a) A windbreak of evergreens, deciduous trees, and shrubs protects a Kansas farmstead (from http://photogallery.nrcs.usda.gov). (b) Evergreen and broadleaf tree windbreak (From http://www.forestry.iastate.edu/ext/).

Generally, the distance of full protection from a windbreak is

$$d = 17h\left(\frac{v_m}{v}\right)\cos(\theta) \qquad \textbf{20.17}$$

where d = distance of full protection (L),

h = height of the barrier in the same units as d (L),

v_m = minimum wind velocity at 15-m height required to move the most erodible soil fraction (L/T),

v = actual wind velocity at 15-m height (L/T),

θ = the angle of deviation of prevailing wind direction from the perpendicular to the windbreak.

Chepil (1959) reported that v_m for a smooth bare surface after erosion has begun but before wetting by rainfall and subsequent surface crusting, was about 9.6 m/s.

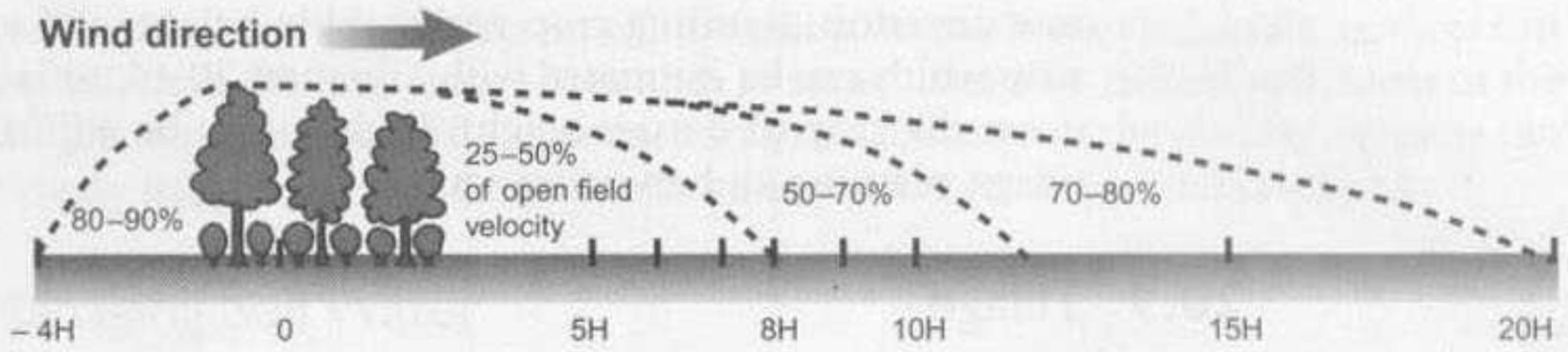


Figure 20–4
Zones of reduced wind velocity downwind of barrier as percentage of open field velocity for a windbreak with height H. (Iowa State University, 1997)

Equation 20.16 is valid only for wind velocities below 18 m/s. It may also be adapted for estimating the width of strips by using the crop height in the adjoining strip in the equation.

In shelterbelts, a tight row of shrubs on the windward side is desirable. When combined with conifers and low, medium, and tall deciduous trees, the shelterbelt provides a compact and rather dense barrier. Such an extensive shelterbelt may not always be required. Single-row belts are preferred in many areas because fewer trees and less land are needed, and the shelterbelt is easier to cultivate and maintain. Local recommendations should be followed for varieties, spacings, and other practices.

20.8 Strip Cropping

Strip cropping consists of growing alternate strips of clean-cultivated and close-growing crops in the same field (Figure 20-5). Field strip cropping is laid out parallel to a field boundary or other guideline. In some of the plains states, strips of fallow and grain crops are alternated. The chief advantages of strip cropping are (1) physical protection against blowing, provided by the vegetation; (2) soil erosion reduced within and between the vegetated strips; (3) greater conservation of water, particularly from snowfall; and (4) the possibility of earlier harvest. The chief disadvantages are machine problems in farming narrow strips and greater number of edges to protect in case of insect infestation.

The strips should be of sufficient width to be convenient to farm, yet not so wide as to permit excessive erosion. Strip width depends on the wind speed and direction,

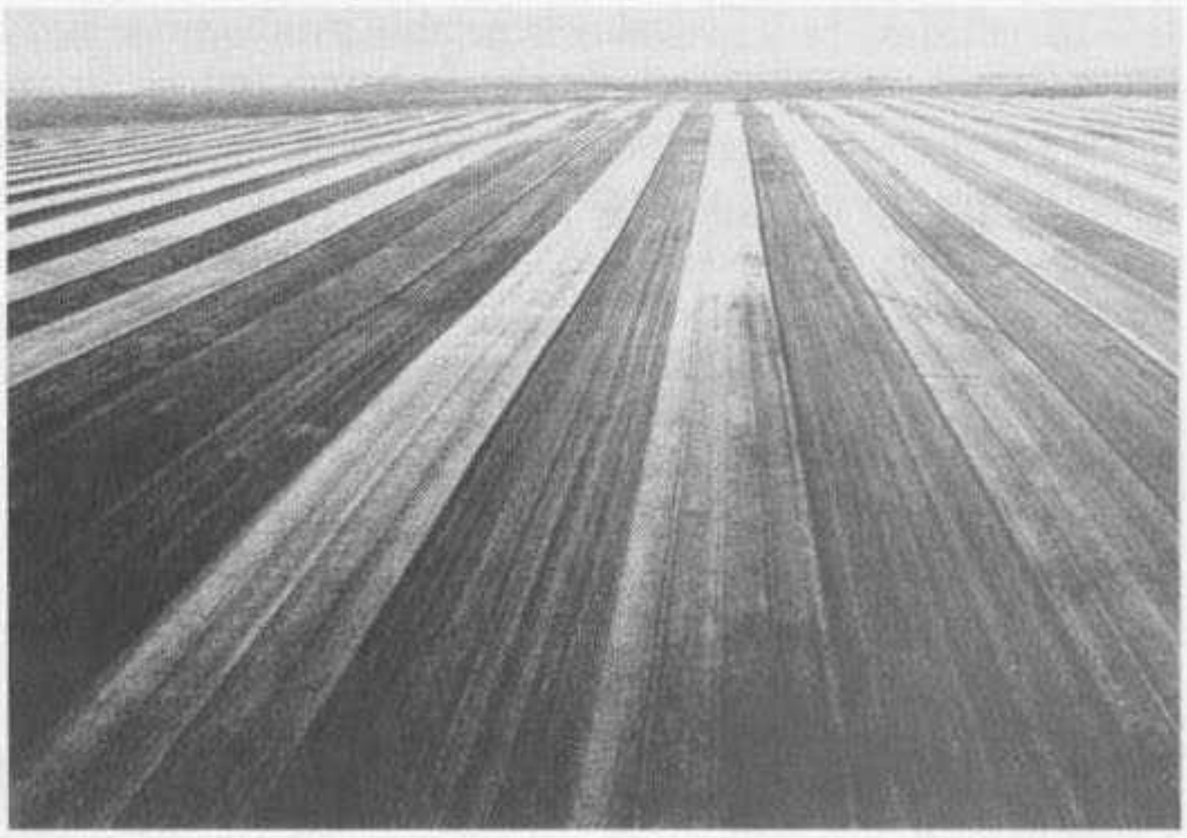


Figure 20–5
Parallel strip cropping to reduce wind erosion. (ARS, 2003)

row direction, standing crop and stubble height, and erodibility of the soil. The strip width can be estimated with Equation 20.16, or is sometimes set at about 10 times the crop or barrier height. Widths may be adjusted to match the width of tillage, planting, or harvesting equipment.

20.9 Tillage

The objective of tillage for wind erosion control is to produce a rough, cloddy surface with some plant residue exposed on the surface. To obtain maximum roughness, the land should be cultivated as soon after a rain as possible to obtain large aggregates.

Ridges from tillage should be normal to the direction of prevailing wind for erosion control. The decrease in wind velocity and change in direction between the ridges cause soil deposition (Figure 20-6). In some areas, ridge tillage systems have completely eliminated wind erosion (Walker & Peterson, 1985).

Tillage is sometimes used as an emergency control measure. Soil blowing usually starts in a small area where the soil is less stable or is more exposed than in other parts of the field. If the entire field starts to blow, it is sometimes recommended that the surface be made rough and cloddy as soon as practicable. This tillage should begin at the windward side of the field and continue by making widely spaced trips across the field. When the field has been stripped, the areas between the strips may then be cultivated.

Crop residues on the surface are an effective means of erosion control, especially when combined with a rough soil surface. This practice is usually called stubble mulch tillage. Crop residues reduce wind velocity and trap eroding soil. Short stubble is generally less effective than long stubble. A mixture of straw and stubble on the surface provides more protection against erosion than equivalent amounts of straw or stubble alone. The higher the wind velocity, the greater the quantity of crop residue required. The effectiveness of surface residue on reducing wind erosion is shown by the importance of the vegetation cover terms in soil erosion prediction, as was demonstrated in the final step of Example 20.1.

20.10 Mechanical Methods

Mechanical barriers such as windbreaks are of limited importance for field crops, but they are frequently employed for the protection of farmsteads, areas of high-value vegetable production, and beach restoration. Mechanical control methods include slat or brush fences, board walls, and vertical fabrics, as well as the surface protection, such as brush matting, rock, and gravel. These techniques are sometimes used for the protection of vegetable crops in organic soils as well.

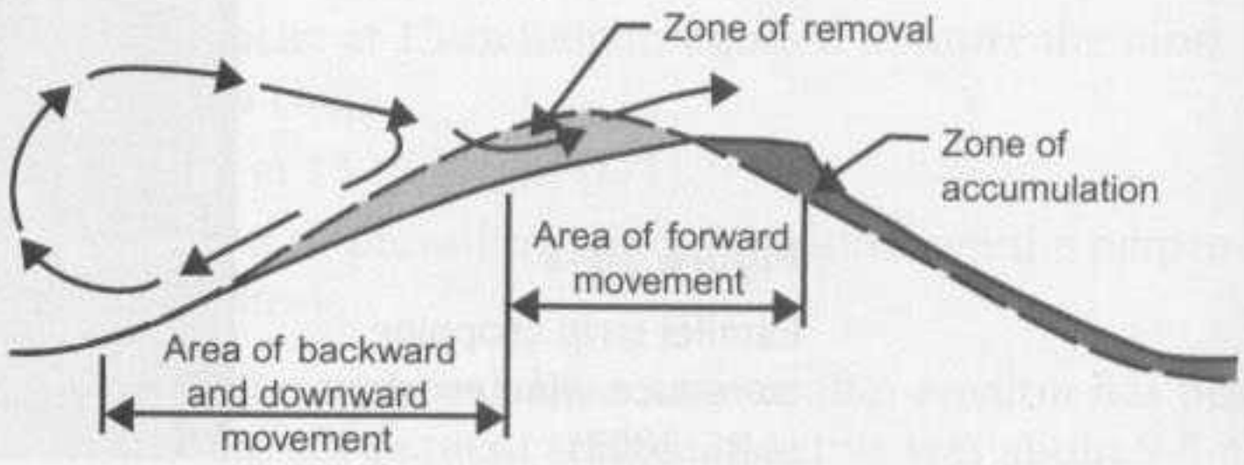


Figure 20–6
Soil movement across ridges as impacted by wind turbulence. (NRCS, 2002)

Terraces have some effect on wind erosion. In the Texas Panhandle, terraces lost less soil than the interterrace area and, in some instances, gained soil. Most of the soil that was lost from the interterrace area was collected in the terraces. Terraces can increase trapping of eroded sediment, and conserve water (see next section).

20.11 Managing Soil Water

The conservation of soil water, particularly in arid and semiarid regions, is important for wind erosion control and for crop production. Water conservation methods fall into three categories: increasing infiltration, reducing evaporation, and preventing unnecessary plant growth. Water conservation management practices include level terracing, contouring, mulching, and selection of suitable crops. Tillage of fallow lands immediately following precipitation will reduce weed growth to conserve water and will also tend to form clods, reducing water movement to the surface, and increasing the resistance of the surface to detachment.

Level or conservation bench terraces are often used to retain water to reduce wind erosion. They are suitable on slopes under about 4 percent so that the water can be spread over a relatively large area (Chapter 8). Such practices as contouring, strip cropping, and mulching are effective in increasing the total infiltration and thereby the total soil water available to crops. Field strip cropping generally does not conserve as much water as contour strip cropping, but it is somewhat more effective in reducing surface wind velocities.

Organic soils do not blow appreciably if the soil is moist. If the subsoil is wet, rolling the soil with a heavy roller will increase capillary movement and moisten the surface layer. Controlled drainage where the water level is maintained at a specified depth may also reduce blowing. In irrigated areas overhead sprinklers can be used to increase surface water contents during critical times of the year.

20.12 Conditioning Topsoil

Since wind erosion is influenced to a large extent by the size and apparent density of aggregates. An effective method of conditioning the soil against wind erosion is to use practices that produce nonerosive aggregates (greater than 1 mm in diameter). During the periods of the year when the soil is bare or has a limited amount of crop residue, control of erosion may depend on the degree and stability of soil aggregation.

Tillage may or may not be beneficial to soil structure, depending on the water content of the soil, type of tillage, and number of operations. For optimum resistance to wind erosion in semiarid regions, it is desirable to perform primary tillage as soon as practical after a rain. The number of operations should be kept to a minimum, because tillage has a tendency to reduce soil aggregate size. Secondary tillage for seedbed preparation should be delayed as long as practical.

Soil structure is affected by the climatic influences such as rainfall and temperature distributions. Freezing and thawing generally have a beneficial effect in improving soil structure where sufficient water is present; however, in dry regions the soil is more susceptible to erosion because of rapid breakdown of the clods into smaller aggregates. Resistance to erosion can also be increased with applications of chemicals such as polyacrylamide to the surface (Armbrust, 1997).

Internet Sites

Environmental Protection Agency Office of Air and Radiation
http://www.epa.gov/oar/

USDA Agricutural Research Service Wind Erosion Research Unit
http://www.weru.ksu.edu. Key search term: wind erosion

USDA NRCS, New Mexico Wind Erosion Equation Spreadsheet
http://www.nm.nrcs.usda.gov/technical/tech-notes/agro.html
Links to windbreak design and management resources

http://ilvirtualforest.nres.uiuc.edu. Key search term: windbreak

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