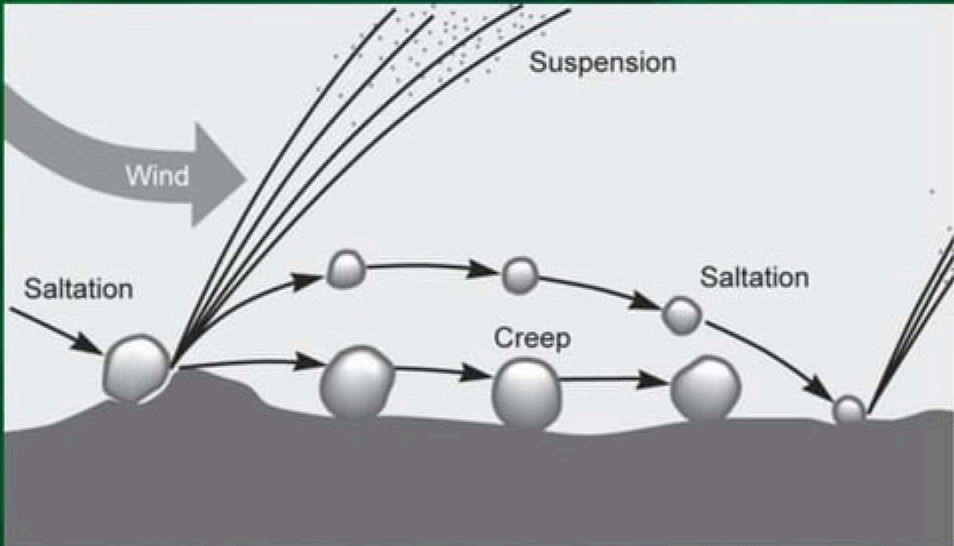
Wind erosion

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.

Types of Soil Movement



Mechanics of Wind Erosion

- 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 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.

Mechanics of Wind Erosion

- 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.
  - It is estimated that the potential carrying capacity per cubic kilometer of the atmosphere is many tonnes of soil, depending on the wind velocity.

Mechanics of Wind Erosion

- 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.

Estimating Wind Erosion

- The Wind Erosion Equation (WEQ) method is presented as an interaction among five factors:

$$E = f(I, K, C, L, V)$$

where

E = estimated average annual soil loss (Mg ha-1 y-1),

I = wind 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.

Estimating Wind Erosion

- Wind Erodibility Index, I

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

- 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.

Estimating Wind Erosion

- Roughness Factor, K.
- To estimate K, it is necessary to first estimate the ridge roughness from the equation:

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

- where *Kr* = ridge roughness in mm,
- *h* = ridge height in mm,
- *d* = ridge spacing in mm.

From the ridge roughness *Kr*, the roughness factor *K* can be calculated by the re- gression relationship derived from Woodruff and Siddoway (1965):

$$K = 0.34 + \frac{12}{K_r + 18} + 6.2\times10^{-6} K_r^{\,2} \qquad (20.4)$$

Estimating Wind Erosion

- 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 can be calculated from the relationship

$$SG = a R_w^b \quad (20.5)$$

- Where,

SG = small grain equivalent (kg/ha),

a, b = crop constants from Table 20.3,

Rw = quantity of residue to be converted to small grain equivalent (kg/ha).

Estimating Wind Erosion

- From the small grain equivalent, the vegetative cover factor V (Mg/ha) can be calculated from:

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

Predicting Erosion

- 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} as:

$$E_1 = I \tag{20.8}$$

2. Calculate E_2 from soil and surface properties contained in Equation 20.4:

$$E_2 = I\,K \tag{20.9}$$

3. Calculate E_3 by including climate the climate factor C presented in Figure 20.1, or from local information, as:

$$E_3 = I\,K\,C \tag{20.10}$$

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

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

Predicting Erosion

5. Calculate the field length factor WF as:

$$WF\,(\text{Mg ha}^{-1}\,\text{y}^{-1}) = E_2 \times \left(1.0 - 0.122\left[\frac{L}{L_o}\right]^{-0.383}\right) e^{L/L_o} \qquad (20.12)$$

where L = unsheltered distance (m).

6. Calculate E_4, the interaction of surface, soil, climate, and length effects, as:

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

7. Calculate the effects of vegetation through two factors based on the vegetation cover factor V:

$$a = e^{-0.759V - 4.74\times10^{-2}V^2 + 2.95\times10^{-4}V^3} \qquad (20.14)$$

$$b = 1.0 + 8.93\times10^{-2}V + 8.51\times10^{-3}V^2 - 1.5\times10^{-5}V^3 \qquad (20.15)$$

8. Incorporate the vegetation factors into the erosion estimate as:

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

Example 20.1

A field in Central Kansas (from Figure 20.1, $C = 0.8$) is 800 m long. From a sieve analysis, it is determined that the soil has 25% nonerodible clods (>0.84 mm). Several knolls with 3% 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 … wind erosion on this field?

Solution. Th… en on the previous page:

(1) Calculat…

(2) Calculat…

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).

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

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

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

(4) Calculate E_2 from Equation 20.9 as:

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

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

$$E_3 = 251 \times 0.5 \times 0.8 = 101 \text{ Mg ha}^{-1}\text{y}^{-1}$$

(6) Calculate L_o from Equation 20.11 as:

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

(7) Calculate WF from Equation 20.12 as:

$$WF = 126 \times \left(1.0 - 0.122 \left[\frac{800}{2877} \right]^{-0.383} \right) e^{800/2877} = 134$$

(8) Calculate E_4 from Equation 20.13 as:

$$E_4 = \left(134^{0.348} + 101^{0.348} - 126^{0.348} \right)^{2.87} = 107 \text{ Mg ha}^{-1}\text{y}^{-1}$$

(9) Calcu … Table 20.3, $a =$ 0.353

(10) Calcu

(11) Calcul

$a = \exp(-$ … $= 0.513$

$b = 1.0 +$ … $^{3} = 1.08$

(12) Incorpo… ith Equation 20.16:

Thus, the es…

Table 20.3 Crop Residue Coefficients for Predicting Small Grain Equivalent (*SG*) from Crop Residue Properties

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

Control Practices

- 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.
  - 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.

Control Prac

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  - A shelterbelt ... eak,
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    intended for ... r and
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(a)

(b)

Figure 20.3–Typical mechanical barriers: (a) a windbreak of evergreens, deciduous trees, and shrubs protects a Kansas farmstead (source: http://photogallery.nrcs.usda.gov); and (b) evergreen and broadleaf tree shelterbelt along a field boundary (source: http://www.forestry.iastate.edu/ext/).

Control Practices

- Windbreaks and Shelterbelts
  - Depending on the effectiveness of the barrier, reduction in wind velocity can occur for a distance up to 20 times its height.

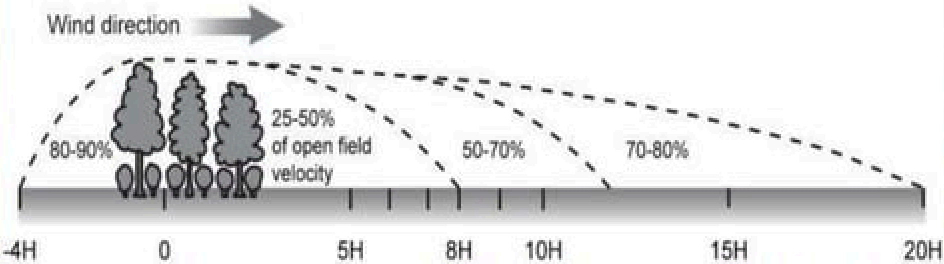

Figure 20.4–Zones of reduced wind velocity downwind of barrier as percentage of open field velocity for a windbreak with height H. (Source: Iowa State University, 1997.)

Control Practices

- Generally, the distance of full protection from a windbreak or shelterbelt is

$$d = 17h\left(\frac{v_m}{v}\right)\cos(\theta) \qquad (20.16)$$

- 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 a height of 15 m required to move the most erodible soil fraction (L/T), =9.6 m/s.
  - v = Actual wind velocity at a height of 15 m (L/T),
  - θ = the angle of deviation of prevailing wind direction from the perpendicular to the windbreak.

Control Practices

- Strip Cropping
- Strip cropping consists of growing alternate strips of clean-cultivated and close- growing crops in the same field (Figure 20.5).
- The chief advantages of strip cropping are
  - (1) physical protection against blowing, provided by the vegetation;
  - (2) reduction of soil erosion with- in 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.

Control Practices

- 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.
  - The decrease in wind velocity and change in direction between the ridges cause soil deposition (Figure 20.6).

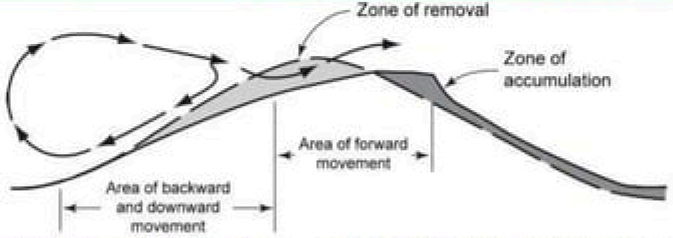

Figure 20.6–Soil movement across ridges as impacted by wind turbulence. (Source: NRCS, 2002.)

Control Practices

- Constructed Barriers
  - Constructed mechanical barriers 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.

Control Practices

- 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.

Control Practices

- Conditioning Topsoil
  - 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.
  - An effective method of conditioning the soil against wind erosion is to use tillage practices that produce nonerosive aggregates (greater than 1 mm in diameter).
  - For optimum resistance to wind erosion in semiarid regions it is desirable to perform primary tillage as soon as practical after a rain.