Wind Erosion
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NREM 461
Dust Bowl Images from the 1930s

Black Sunday April 14, 1933
Al Asad, Iraq, April 26, 2005
Photographs taken by:
Gunnery Sgt. Shannon Arledge & others
Dust Storm in Dallas, Texas
Photographs taken by Charlie Haley
Sat., 24 Feb., 2007 (left column) & Mon. 25 Feb., 2007 (right column)
I. Wind Erosion

A. Types of Wind Erosion

1. **soil creep**: rolling & sliding along the surface of larger particles (~0.5-1 mm in diameter)

2. **saltation**: movement of particles by series of short bounces (~0.05-0.5 mm diameter)
   a. 

3. **suspension**: dust particles, < fine-sand moved // to ground surf & upward (<0.05 mm diameter)
Types of Wind Erosion
Figure 2. Dust is transported in two major global dust transport systems: (1) from the Sahara and Sahel of Africa to the Americas, Europe, and Near East; and (2) from the Takla Makan and Gobi deserts of China, across China, Korea, Japan, and the northern Pacific to North America, sometimes exiting over the Atlantic Ocean. Illustration: Betsy Boynton.

(Garrison et al. 2003)
B. Particles & aggregates >1-2 mm in diameter remain in place & form a “lag concentrate” or “desert pavement.”
Desert pavement in the Las Cruces, NM area
C. Erosiveness of surface wind

1. Wind velocity: measured at 30 ft (9 m) above ground

a. Friction Velocity = $u^* = \sqrt{\frac{\tau_o}{\rho}}$  
   $\tau_o$ = surface sheer stress (dynes/cm$^2$)  
   $\rho$ = air density (g/cm$^3$)  
   $u^*$ = friction velocity (cm/s)

i. Not actual velocity, has same units, related to vel. profile & drag on soil surf

b. Wind velocity related to friction velocity as follows

$$u_z = u^* \left( \frac{\ln(z - D)}{kZ_o} \right) + \phi_o$$

$u_z$ = mean wind velocity at z (cm/s)  
$z$ = height of measuremnt (cm)  
$k$ = von Karman’s constant (<0.4, 0.4 for clear fluid)  
$D$ = zero plane displacement (cm)  
$Z_o$ = effective roughness height (cm)  
$\phi_o$ = adiabatic influence function (usu. = 0)
Wind velocity near the soil surface without (A) and with vegetation (B) (Troeh et al. 2004).
c. **Threshold wind velocity to cause erosion** =

i. depends on soil type, measured 6 in above soil surface

2. **Wind turbulence**
   a. wind strong enough to cause erosion is always turbulent, w/ eddies moving in all directions
   
   b. turbulence important in keeping grains suspended

3. **Wind gustiness**
   a.
4. Prevailing wind direction

a. soil surfaces can become stabilized against prevailing winds by developing protected areas behind nonerodible grains & clods

b. 

(Woodruff & Siddoway 1965)

Fig. 2—Prevailing wind erosion directions in the Great Plains. Degrees indicate deviation of the prevailing wind erosion direction from north-south and percentages indicate per cent of erosion that occurs along that direction.
D. Wind erosion process

1. Detaching capacity (D) of wind

   a. \( D = f(u'^* )^2 \)  
      \( D = \) detaching capacity (g cm\(^{-2}\) s\(^{-1}\))  
      \( u'^* = \) friction velocity, (cm s\(^{-1}\))

   b. D is related to friction velocity & grain size

   c. Soils that protrude higher are struck by stronger winds
2. Transporting capacity of wind
   a. related to wind speed, not soil grain size
   b. total weight of material a specific wind can carry remains relatively constant

3. Soil Deposition
   a. distance a soil is transported depends on wind speed, size & weight of particles
   b. 

(NASA, Garrison et al. 2003)
E. Factors affecting wind erosion:

1. **Soil resistance**, if mass of individual grains is sufficient, particles are nonerodible

   a. **grain/aggregate size**: large grains/aggregates (>1 or 0.84 mm diameter) resist erosion, protect smaller grains in their wind shadow
Relationship of relative erodibility & percent nonerodible clods (Troeh et al. 2004).
b. texture, organic matter effect resistance

i. clays aggregate, coarse sands, gravel too large to be moved

ii. SOM associated with aggregation, stability (high OM soils subject to erosion)

iii. Moisture:

2. **Surface roughness**

a. surface ridges produced by tillage resist erosion, even by >50%

   “...rough surfaces usually reduce erosion because elements of surface roughness absorb much of the drag and leave only a small residual force to strike erodible soil grains.” (Troeh et al., 2004)
Surface soil roughness in a recently bedded field in Texas. (Picture to right is close-up of the field shown above.)
Random roughness of 0.25 inches.

Random roughness of 1.05 inches.

Random roughness of 0.65 inches.

Random roughness of 2.15 inches.
3. **Rainfall**

   a. rain moistens surface soil, & moist soil not eroded by wind

   b. caveat:

4. **Topography**

   a. wind’s erosive force is greatest on hilltops/crests
Lines of equal wind velocity over different topographies. The top line in each diagram represents 14 mi hr$^{-1}$ or 6.25 m s$^{-1}$ (Troeh et al. 2004).
**TABLE 5–1** RELATIVE AMOUNTS OF EROSION FROM LEVEL (1.5% SLOPE) AND FROM SHORT-SLOPING (HUMMOCKY) LAND

<table>
<thead>
<tr>
<th>Slope (%)</th>
<th>Crests</th>
<th>Upper slopes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5 (level)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>3.0</td>
<td>150</td>
<td>130</td>
</tr>
<tr>
<td>6.0</td>
<td>320</td>
<td>230</td>
</tr>
<tr>
<td>10.0</td>
<td>660</td>
<td>370</td>
</tr>
</tbody>
</table>

*Source: From the *Journal of Soil and Water Conservation*, Volume 19, p. 179–181 (Chepil et al., 1964).*

(Troeh et al. 2004)
5. **Length of Exposed Area**

   a. Wind erosion ↑ significantly w/ increasing field length, as wind builds up more speed.

6. **Vegetative & Residue Cover**

   a. Most effective way to prevent wind erosion is to cover soil:
      
      i. Growing plants: some species better than others
      
      ii. Thick mulch of crop residue:
F. Damage from Wind Erosion

1. Loss of topsoil & subsoil
2. Change in texture through sorting
3. Nutrient/productivity loss
4. 
5. 
6. 
7. 
Figure 3. African dust event (bottom) and nondust (top) atmospheric conditions in the Virgin Islands. Distance to islands in background is 2 to 5 kilometers. Photographs: Courtesy of Christina Kellogg.
"Eight persons were injured during the early-morning rush hour today when 20 vehicles rammed together in blinding dust blowing across Interstate 40 just east of the Amarillo city limits."

-Amarillo Globe-Times, 4/13/1971
“Crews cleared burned hulks of cars and trucks off an interstate and tried to identify victims of a pileup that killed 17 people and injured 150 others during a blinding dust storm.”

Coalinga, California, 12/1/1991
G. 3 main ways to reduce wind erosion

1. 

2. 

3. 
H. Windbreaks & Shelterbelts

1. **Windbreaks**: small groups of trees or shrubs planted to protect crops, livestock, people
   a. Branches/biomass must be near ground

2. **Shelterbelts**: extensive groups of trees, shrubs planted to protect fields from erosive winds

3. Effectiveness
   a. Erosion reduction for long distances
   b.
   c.
Wind velocity (m/sec) 12 9.5 13.5 4.5 6.8

(Brady & Weil 2008)
(Photo by Dr. R. Brown)
REVIEW

You want wind erosion? Here’s what you need:

• Loose, finely divided (i.e., poorly structured), dry soil

• Keep soil compacted and/or moist and/or consisting of stable aggregates or clods large enough to resist the wind

• Keep soil surface rough or covered by vegetation or plant residue

Chepil (1957) as cited by Troeh et al. (2004)
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