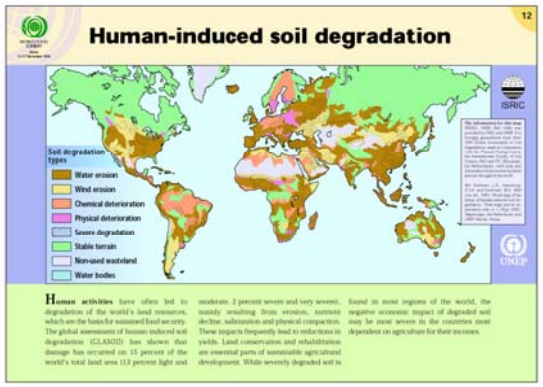
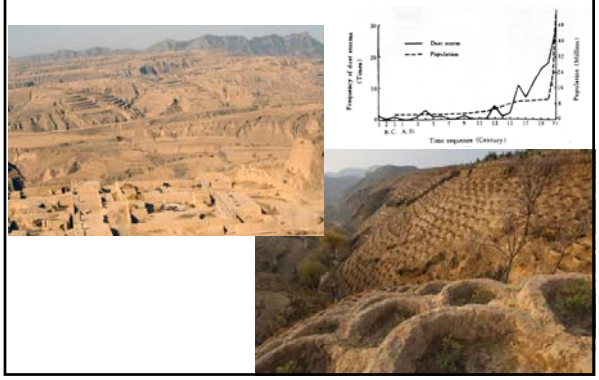
Soil Erosion

- Reading: Chapter 15
- Objectives:
  - Provide an overview of the mechanisms and consequences of soil erosion by water and wind.
  - Link soil erosion to soil formation, to the hydrological cycle and to land use.



The Loess Region of China



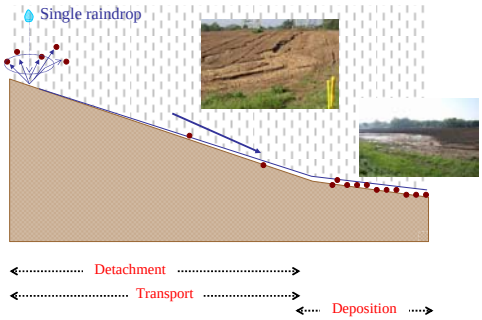
Soil Erosion

- Soil erosion is the process of detachment of soil particles or aggregates.
- Transport of the detached soil particles is also involved but for “short” distances.
- Soil erosion implies that the eroded soil must deposit downstream (sedimentation).
- Damage from erosion, and sedimentation are classified as on-site and off-site.

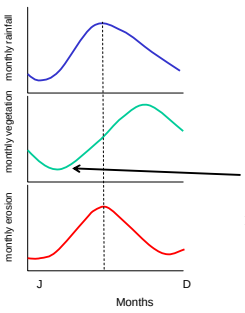
Mechanics of Water Erosion

- Soil erosion by water is a three-step process:
  - *Detachment*
  - *Transport* of the detached particles
  - *Deposition* of the transported material
- The main mechanism of soil transport is *rill flow*. Less important is *overland flow* and *raindrop*.

Mechanics of Water Erosion



Seasonal Cycles of Rainfall, Vegetation and Erosion



Erosion in a cultivated field at Cook Campus resulting from almost 1" rain (May 06).

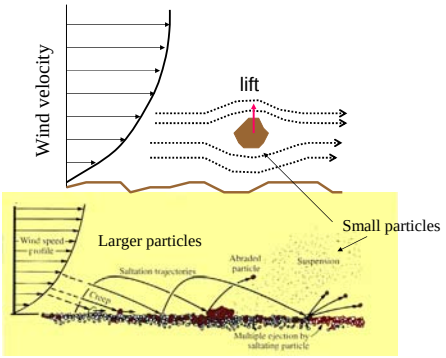
Damage Associated with Soil Erosion and Deposition

On-site	Off-site
Loss of plant nutrients and organic matter	Siltation of river, streams and reservoirs
Reduced depth of top soil and water storage	Chemical pollution of water and soils
Damage soil structure	Damage of infrastructure
Poorer habitat for soil biota	Burial of off-site crops

Mechanics of Wind Erosion

- Soil erosion by wind occurs by three mechanisms:
  - *Suspension* of the finer particles produced by a gradient in wind velocity.
  - *Saltation* after being lifted the larger particles fell back to the ground.
  - *Soil creep* of the larger particles (never lifted by wind).

Mechanics of Wind Erosion



Factors Affecting Soil Erosion

Energy factors

LOW.....	rainfall erosivity..	HIGH
LOW.....	runoff volume.....	HIGH
LOW.....	wind strength.....	HIGH
LOW.....	relief.....	HIGH
GENTLE..	slope angle.....	STEEP

Resistance factors

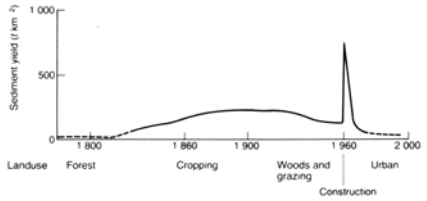
LOW.....	soil erodibility..	HIGH
HIGH.....	infiltration capacity.....	LOW
GOOD.....	soil management....	POOR

Protection factors

LOW.....	population density..	HIGH
DENSE.....	plant cover.....	NONE
LOW.....	pressure of use.....	HIGH
GOOD...	land management.	POOR

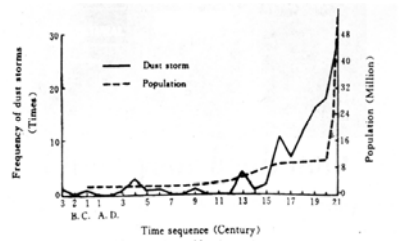
UNLIKELY... SOIL EROSION...LIKELY

Sediment Yield and Land Use in Maryland



- Sediment yield is the amount of sediment that moves through a designated point at the outflow end of a channel, plot, field, or watershed.

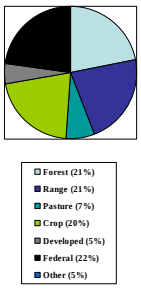
Population and Frequency of Dust Storms in China

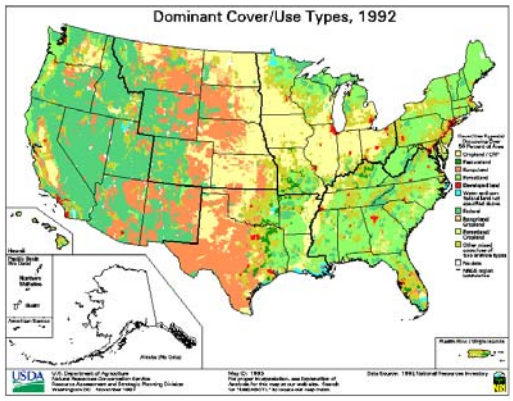


- The frequency and intensity of dust storms are increasing with population in northwest China.

U.S. Land Use

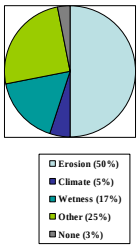
- The type of land use has a significant bearing on the amount of potential erosion from an area.
- Note that the land is almost equally divided between cropland, rangeland, and forest land.





Dominant Limitations to Grow Crops in U.S. Soils

- Note that only 3% of the land has no limitations to grow crops.
- Erosion and sedimentation are the greatest (50%) potential problem.
- Among “other” limitations are: shallowness, lack of water, stoniness, or salinity.



Erosion and Crop Yield

Table 4.2—Mean loss in annual yield per ton of soil erosion

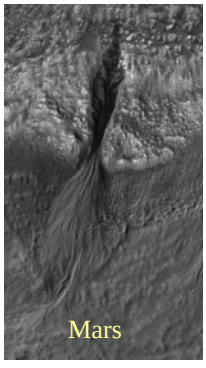
Region	Crop	Experiments	Mean yield	Mean yield loss per ton of soil erosion	
		Number	*Tons per hectare*	*Kg per hectare*	*% of mean yield*
Africa	Maize	42	2.6	0.9	0.03
Asia	Maize	4	1.7	0.7	0.04
	Millet	2	0.3	0.1	0.03
	Soybeans	4	0.9	-0.5	-0.01
	Wheat	4	3.0	0.7	0.02
Australia	Potatoes	2	54.1	3.6	0.01
	Wheat	16	1.2	0.5	0.04
Europe	Millet	2	0.3	0.1	0.02
	Potatoes	2	11.4	0.6	0.00
	Soybeans	1	0.6	0.1	0.02
	Wheat	8	3.5	0.2	0.00
Latin America	Maize	15	2.9	1.4	0.05
	Potatoes	1	20.2	0.7	0.00
	Soybeans	4	2.1	0.6	0.03
	Wheat	1	2.1	0.4	0.02
North America	Maize	131	6.2	0.6	0.01
	Potatoes	3	30.5	127.0	0.42
	Sorghum	17	4.2	0.1	0.00
	Soybeans	43	2.1	0.3	0.01
	Wheat	64	2.6	0.4	0.01

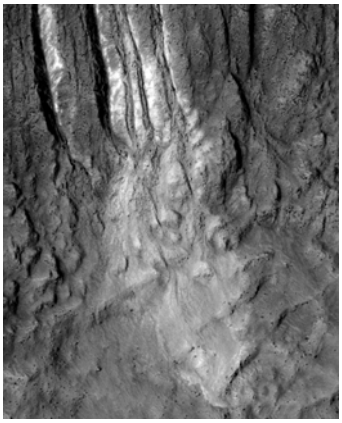
Table 4.4—Estimated value of potential annual erosion-induced production losses by crop and continent

Region	Crop	Total production[1]	Production loss	Value of total production[2]	Value of production loss[2]	Production loss
		Thousand tons per year		*Million $ per year*		*% per year*
Africa	Maize	41,198	202	3,000	15	0.49
	Subtotal	--	--	3,000	15	0.49
Asia	Maize	162,289	961	11,820	70	0.59
	Millet	12,693	64	923	5	0.51
	Soybeans	23,493	-254	4,230	-46	-1.08
	Wheat	254,338	740	23,898	69	0.29
	Subtotal	--	--	40,870	98	0.24
Australia	Potatoes	1,872	2	241	<1	0.12
	Wheat	22,739	152	2,137	14	0.67
	Subtotal	--	--	2,378	15	0.61
Europe	Millet	1,060	2	77	<1	0.23
	Potatoes	136,832	51	17,651	7	0.04
	Soybeans	2,3134	5	417	1	0.22
	Wheat	181,517	74	17,055	7	0.04
	Subtotal	--	--	35,200	15	0.04
Latin America	Maize	74,608	704	5,434	51	0.94
	Potatoes	16,281	2	2,100	<1	0.01
	Soybeans	55,426	184	9,979	33	0.33
	Wheat	21,720	58	2,041	5	0.27
	Subtotal	--	--	19,554	90	0.46
North America	Maize	259,122	399	18,872	29	0.15
	Potatoes	25,903	1,031	3,341	133	3.98
	Sorghum	13,811	8	897	1	0.06
	Soybeans	77,879	191	14,021	34	0.24
	Wheat	90,380	96	8,490	9	0.11
	Subtotal	--	--	45,622	206	0.45
Total[3]	Maize	537,217	2,266	39,126	165	0.42
	Potatoes	180,888	1,086	23,335	140	0.60
	Millet	13,752	67	1,000	5	0.48
	Sorghum	13,811	8	897	1	0.06
	Soybeans	159,110	126	28,646	23	0.08
	Wheat	570,675	1,120	53,621	105	0.20
	Total	--	--	146,625	439	0.30

[1] Production data from FAO (2000).
[2] Prices based on projected 2000/01 crop prices from USDA (2001).
[3] Totals fall short of global total production of these crops because they exclude crop-region combinations for which no plot-level studies were found (e.g., wheat in Africa).
Source: den Biggelaar et al. (forthcoming b).

Evidence of Soil Erosion by Water



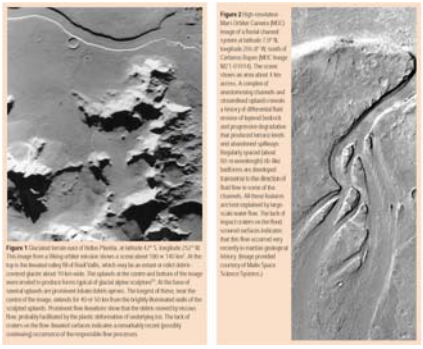


RECENT GULLY ACTIVITY

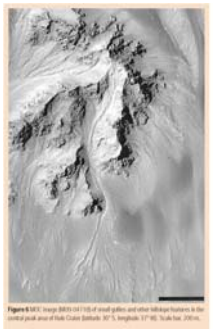
Malin et al. [2006] present evidence from repeat imaging that flows have occurred in at least one gully system during the past decade. This flow is bright-colored, and several other examples of bright, presumably recent flows have been identified.

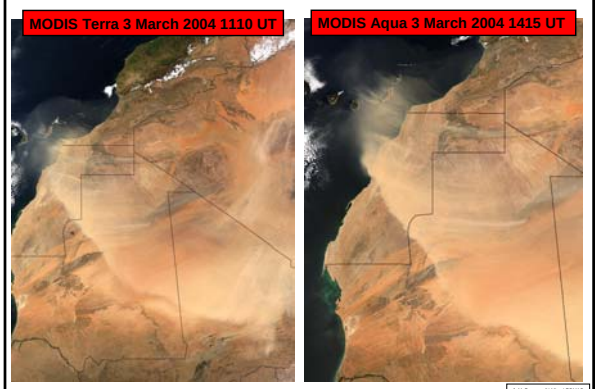
They argue this is evidence for formation by groundwater flow

Evidence of Water Flow in Mars



Evidence of Water Erosion in Mars





Dust Storms

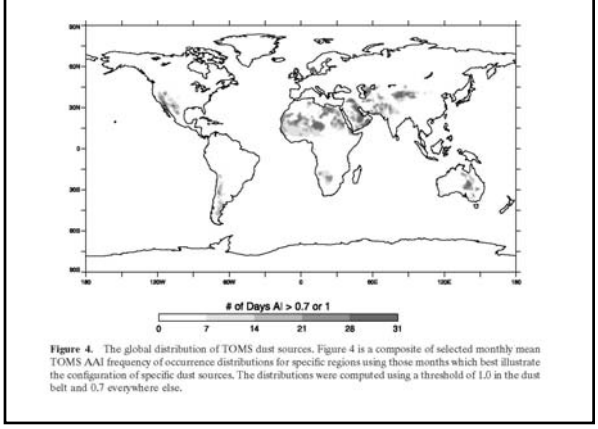
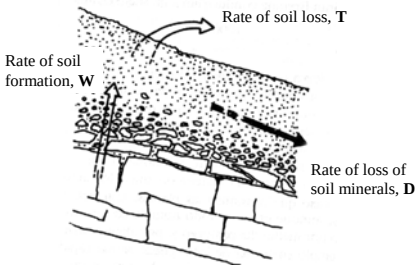
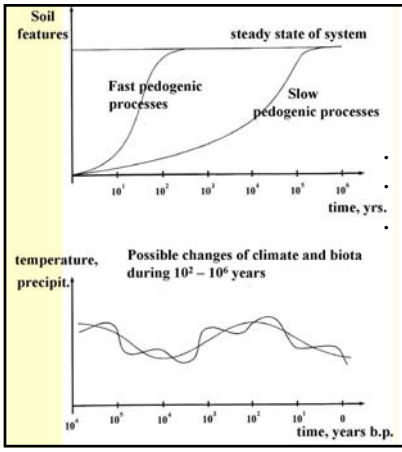


Figure 4. The global distribution of TOMS dust sources. Figure 4 is a composite of selected monthly mean TOMS AAI frequency of occurrence distributions for specific regions using those months which best illustrate the configuration of specific dust sources. The distributions were computed using a threshold of 1.0 in the dust belt and 0.7 everywhere else.



- For a sustainable system: W = T + D
- The tolerable soil loss (T) is the maximum amount of soil that can be lost without degrading the soils long term productivity.



- Rates of soil formation vary between 0.1 to 750 yr cm^{-1}.
- At steady state the rate of formation is similar to the rate of geological (natural) erosion.
- 1 cm of surface soil represents between 100-150 ton/ha.

The Time Factor

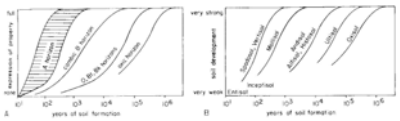
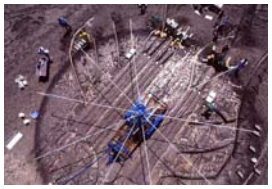


Figure 11.2 Schematic representation of the times needed to attain various properties of soils (A) and orders of soils recognized by the Soil Conservation Service of the US Department of Agriculture (B) (modified from Birkeland 1999; with permission from Oxford University Press).

Research on Soil Water Erosion



Development of the **Universal Soil Loss Equation** (USLE).

- The USLE was developed to provide a prediction of annual soil loss for conservation planning (easy to use).
- Ten experimental sites were established between 1930 and 1942.
- Data was collected during 1950 and 1960 from standard USLE plots.

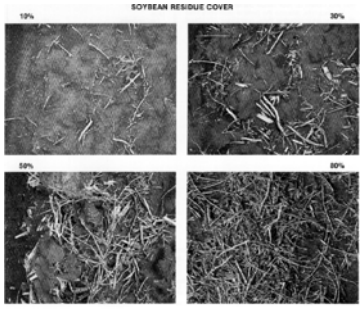
The USLE

$$A = R K LSCP$$

- A: predicted soil loss
  - R, rainfall ***erosivity***
  - K, soil ***erodibility***
  - L, slope length
  - S, slope gradient or steepness
  - C, cover and management
  - P, erosion control practices
- ***Erosivity*** is the potential ability of water or wind to cause erosion.
- ***Erodibility*** is the inherent susceptibility to erosion.

- Rainfall ***erosivity*** is calculated as kinetic energy (E) times intensity (I): EI
- Soil ***erodibility*** factor depends mainly on the ***infiltration capacity*** and ***structural stability*** of a soil.

Cover and Management Factor, C

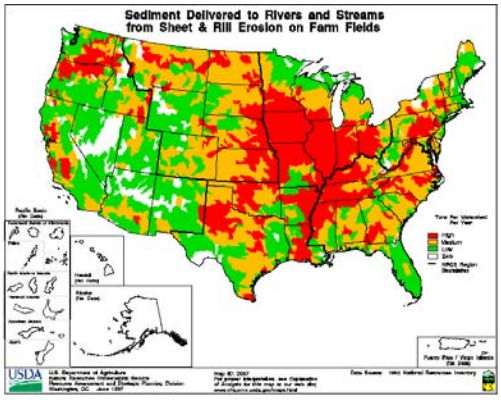


Support Practice Factor, P

- Most common practices are contour cultivation, contour strip cultivation, and terracing.
- Terraces change the LS factor.

Current Prediction Techniques

- The final version of the USLE was published in 1978.
- The next development was the modified USLE (MUSLE) and the revised USLE (RUSLE).
- The current prediction technology has moved away from the USLE. The *Water Erosion Prediction Project* (WEPP) is a process based simulation model

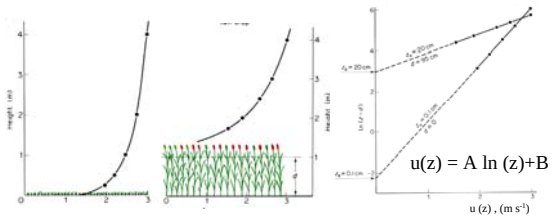


Research on Wind Erosion

Wind tunnels

Samplers

Wind Profiles



Research on Wind Erosion

Applications

The Wind Erosion Prediction Equation WEQ

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

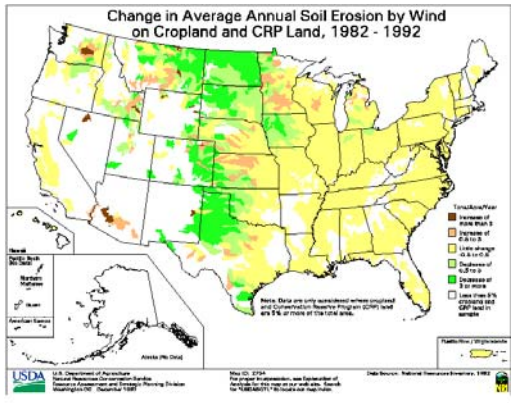
- Predicted soil-loss E is a function of:
  - I', soil erodibility factor
  - K', soil-ridge-roughness factor
  - C', climatic factor
  - L', width of field factor
  - V, vegetative factor
- There is interaction between parameters.

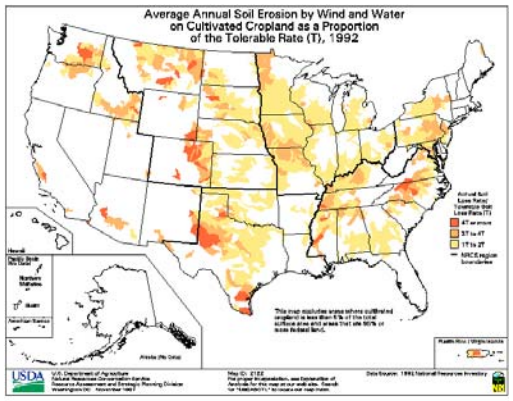
The WEQ

- The I' factor depends on soil erodibility and on slope steepness.
- The K' factor accounts for surface roughness, vegetative cover, and ridges on the surface.
- The C' factor depends on wind velocity and water content of surface soil.
- The L' factor refers to the unsheltered distance in the downwind direction.
- The V refers to the amount and nature of the vegetative cover.

Current Prediction Techniques

- Modeling developments in wind erosion are slower than in water erosion.
- The revised WEQ (RWEQ) is almost finished and is being tested in the field.
- The Wind Erosion Prediction System (WEPS) is a computer model that computes wind erosion on a daily basis.





Positive Impact of Conseravtion Practices