Land Degradation and Soil Erosion

Degraded Land – resulting in reduced productivity

~ 5 billion ha (@ 43% of Earth's vegetated surface)

~ @ 1/3 due to overgrazing

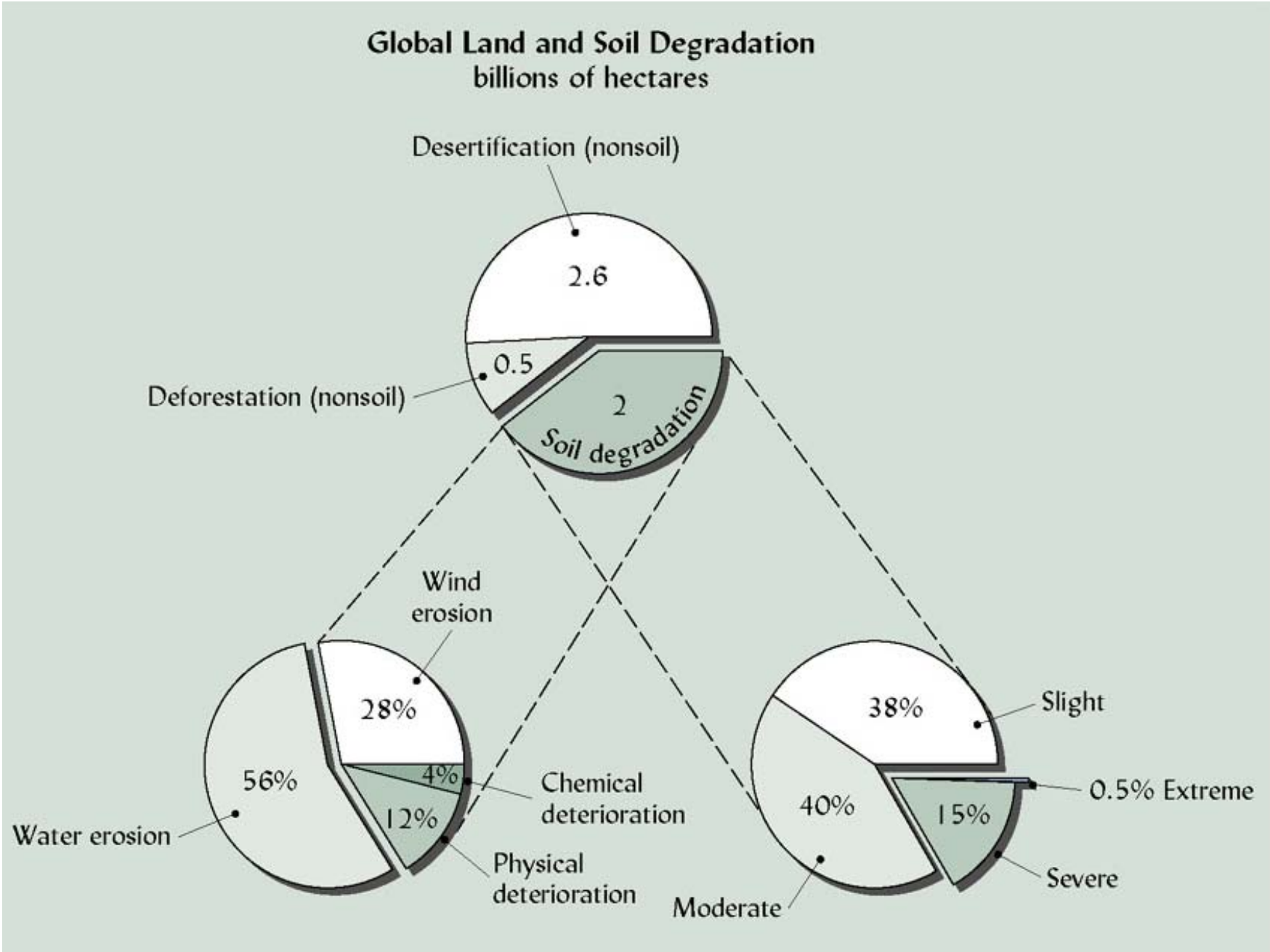
~ 3.6 billion ha associated with desertification

~ a major cause is overgrazing

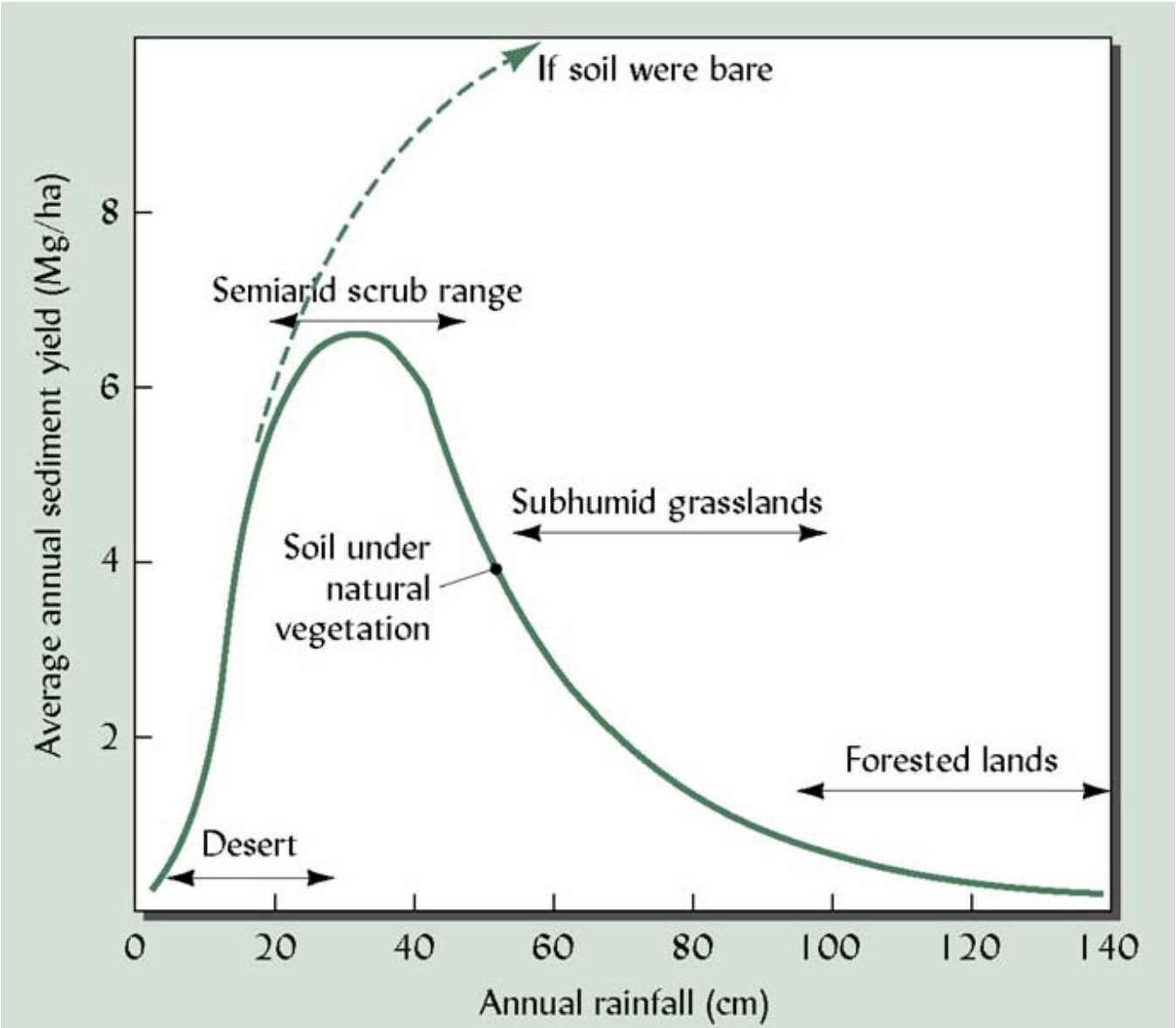
~ 0.5 billion ha due to tree felling in humid tropics

Soil degradation is greatly responsible for @ 2 billion ha of the 5 billion ha

@ 85% of this is due to wind & water erosion


Global Land and Soil Degradation
billions of hectares
Desertification (nonsoil)
2.6
0.5
Deforestation (nonsoil)
2
Soil degradation
Wind
erosion
28%
56%
4%
Chemical
deterioration
12%
Water erosion
Physical
deterioration
38%
Slight
0.5% Extreme
40%
15%
Moderate
Severe

Soil Erosion



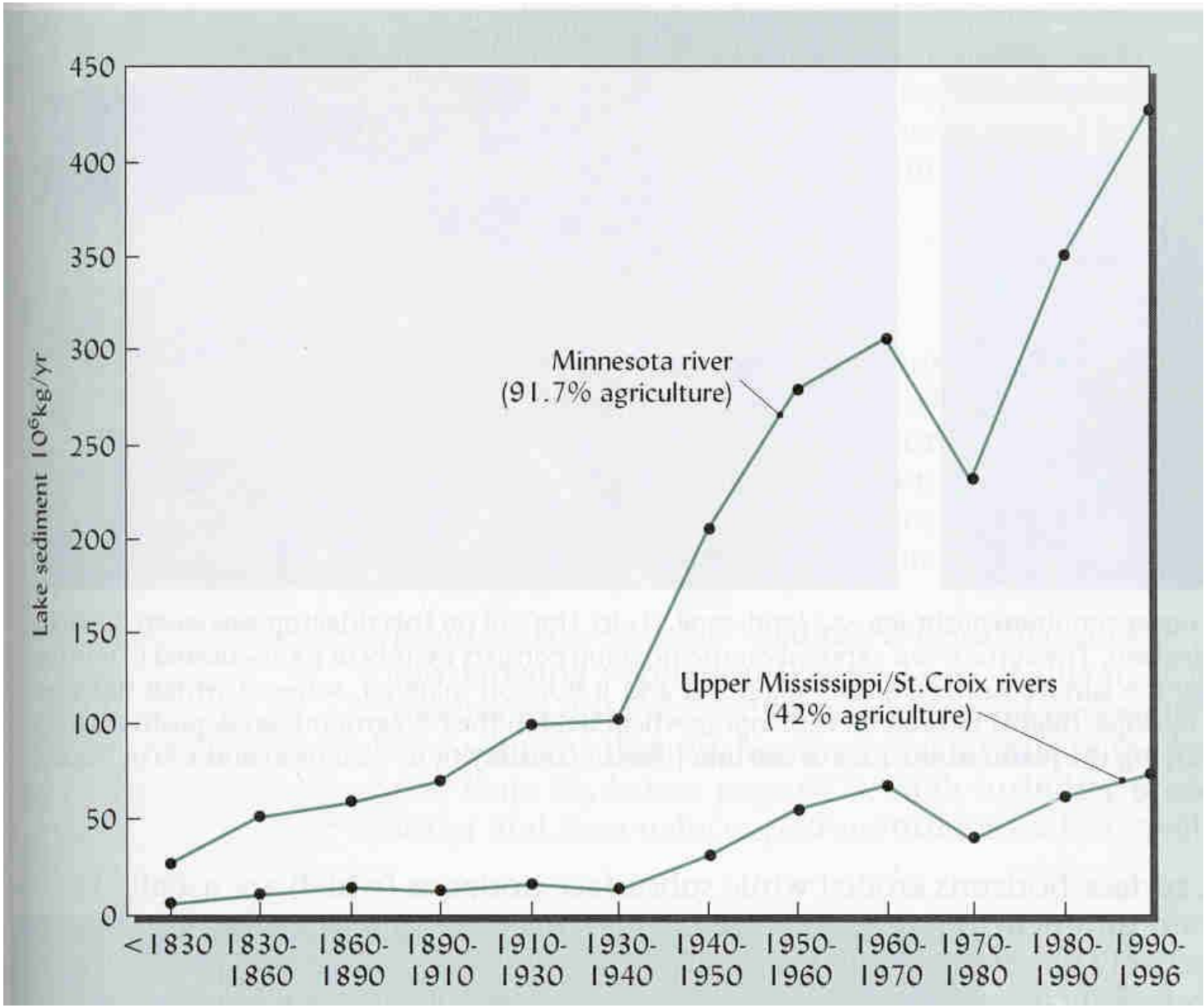

Lake sediment 10^6kg/yr
450
400
350
300
250
200
150
100
50
0
Minnesota river
(91.7% agriculture)
Upper Mississippi/St.Croix rivers
(42% agriculture)
<1830
1830-1860
1860-1890
1890-1910
1910-1930
1930-1940
1940-1950
1950-1960
1960-1970
1970-1980
1980-1990
1990-1996

TABLE 17.1 Annual Sediment Loads for Nine of the World's Major Rivers, Including the Mississippi River

River	*Countries*	*Annual sediment load, million Mg*	*Erosion, Mg/ha drained*
Yangtze	China	1600	479
Ganges	India, Nepal	1455	270
Amazon	Brazil, Peru, etc.	363	13
Mississippi	United States	300	93
Irrawaddy	Burma	299	139
Kosi	India, Nepal	172	555
Mekong	Vietnam, Thailand, etc.	170	43
Red	China, Vietnam	130	217
Nile	Sudan, Egypt, etc.	111	8

Data from different sources compiled by El-Swaify and Dangler (1982).

Soil Erosion - reduces soil productivity:

1. Selectively washes/blows away clay and organic matter (with their nutrients)

2. Reduces pedon thickness, volume of soil providing water & nutrients to roots.

3. Impedes machinery and animal movement (severe cases)

   - increases pollution in streams, lakes (sediments, nutrients)

Soil Susceptibility to Erosion depends on:

1. **Texture - silt-sized particles (0.002 - 0.050 mm) are most easily detached & transported (eg. loess soils)**

2. **Structure -**
   - **aggregation resists detachment & transport**
   - **stabilized by organic matter, Fe & Al oxides, clays**
   - **improves infiltration**

   (low permeability layer makes soil erosive)

3. **Slope**

   Level land erodes very slowly because of low runoff velocity

GRAVITY EROSION

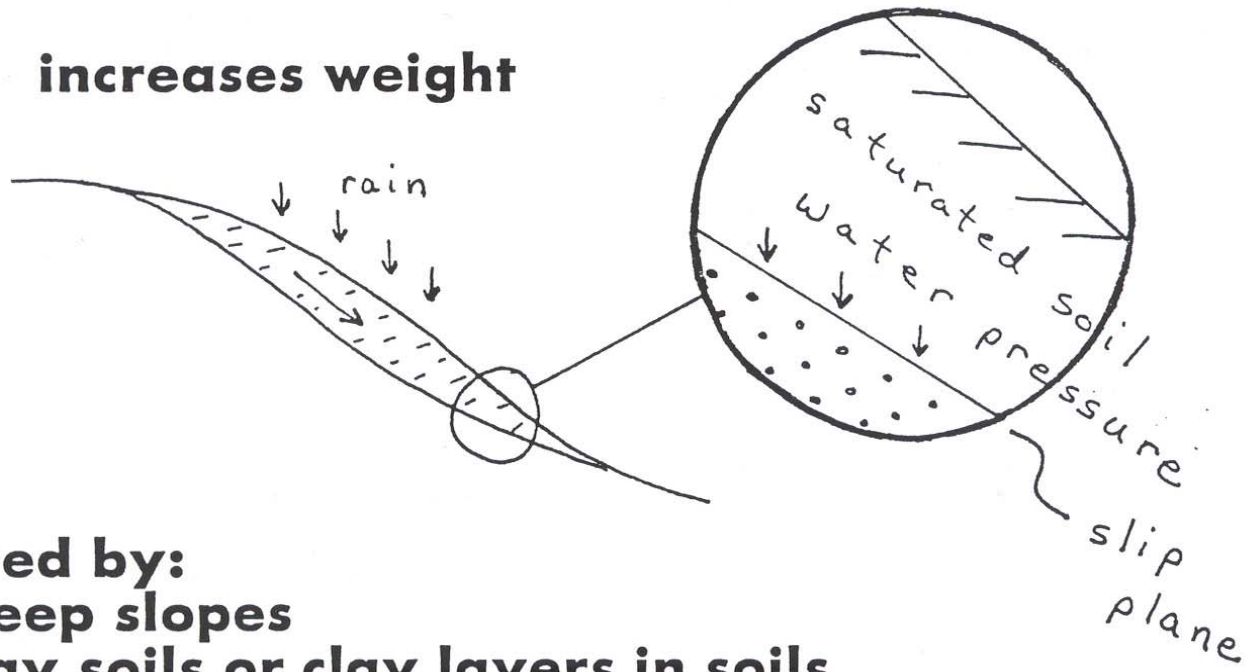
Movement of large masses of soil due to the force of gravity.

LANDSLIDE - rapid
SOIL CREEP - slow, persistent

Usually assisted by water which:

1) **decreases friction holding mass in place**

2) **increases weight**



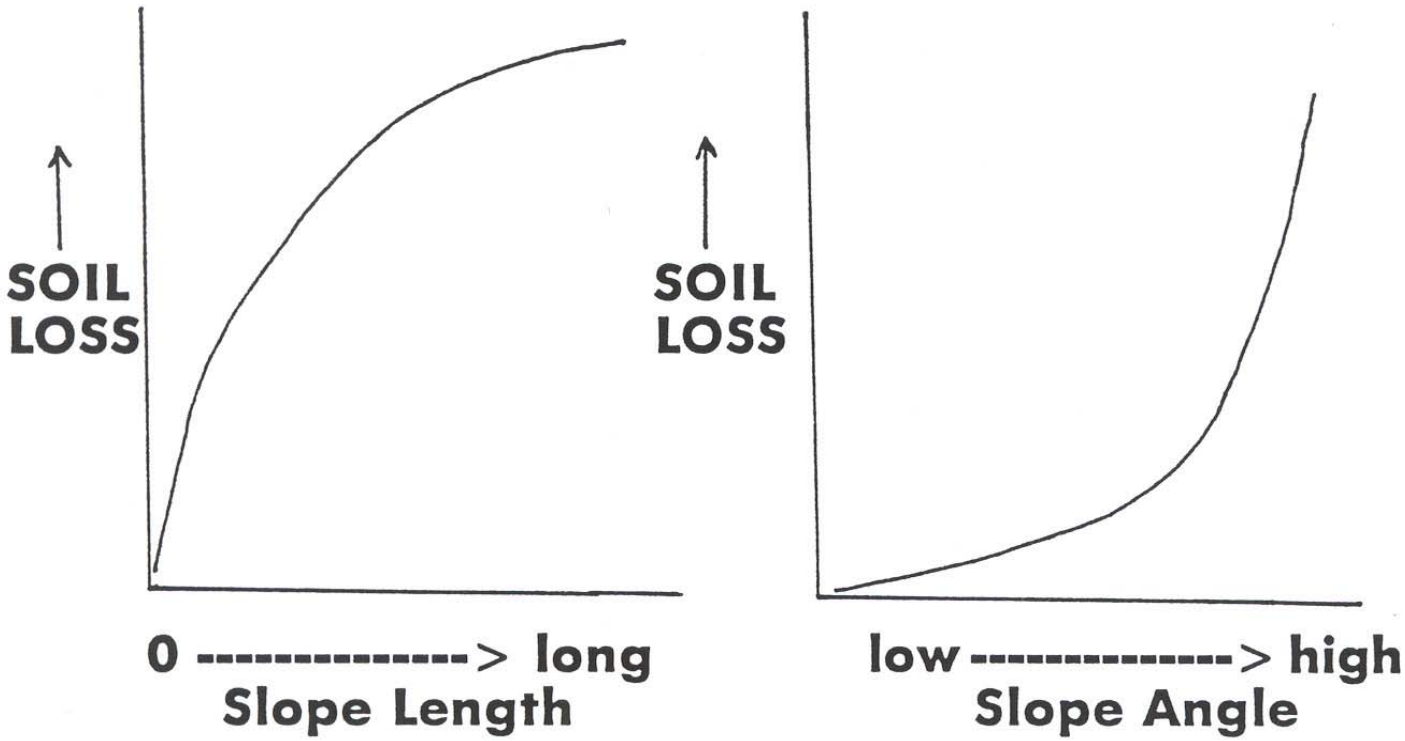
Favored by:

- **steep slopes**
- **clay soils or clay layers in soils**
  - **(high water-holding capacity, slowly draining)**

Prevented by:

vegetation with deep roots → **use water, increase friction**

vegetation with deep roots → **root binding**

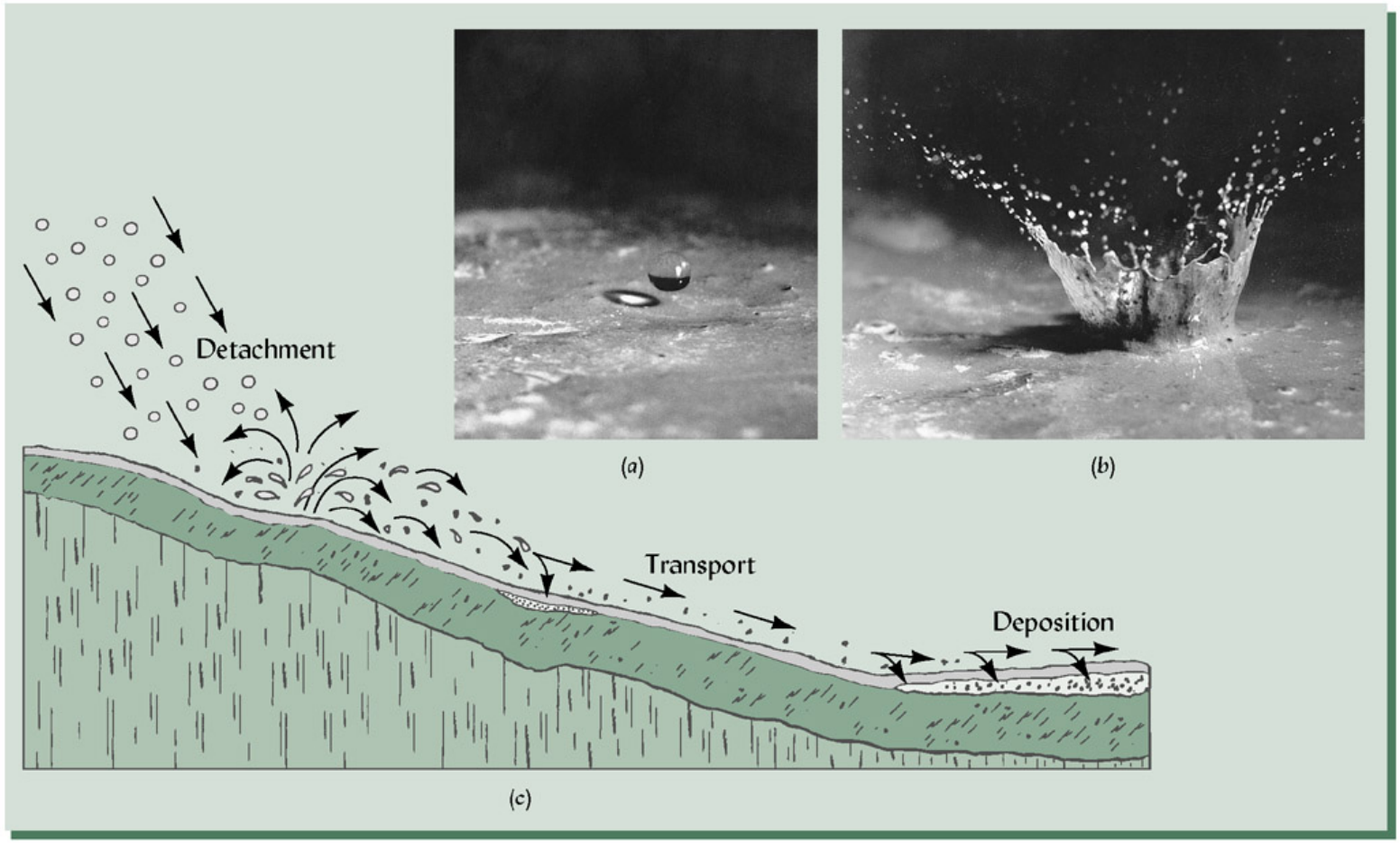

SOIL
LOSS
0 ----------> long
Slope Length
SOIL
LOSS
low ----------> high
Slope Angle

Erosion by Water

A natural geologic process
(created Grand Canyon, Louisiana)
But: accelerated by poor management
(eg. soil left bare, slopes plowed across contour)

Process

1. Rain drop detachment
2. Transport (overland flow or runoff)
3. Deposition

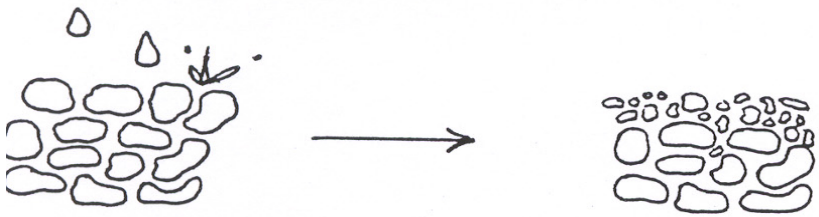

Detachment
Transport
Deposition
(a)
(b)
(c)

Overland flow is favored by ponding, result of:

Raindrops sealing soil surface
Rainfall exceeding infiltration

PHYSICAL DEGRADATION

Surface Sealing & Crusting -



IMPACT DISAGGREGATION

SEALING

dry

CRUSTING

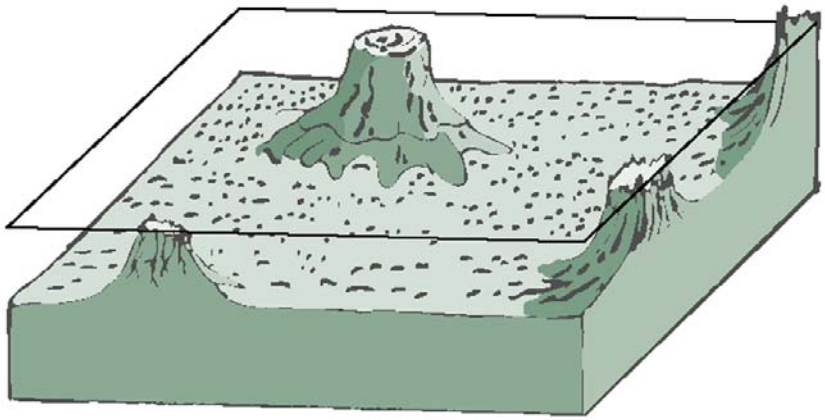
Restricts water entry
Increases runoff, erosion
Impedes seedling emergence

Overland flow is favored by ponding, result of:

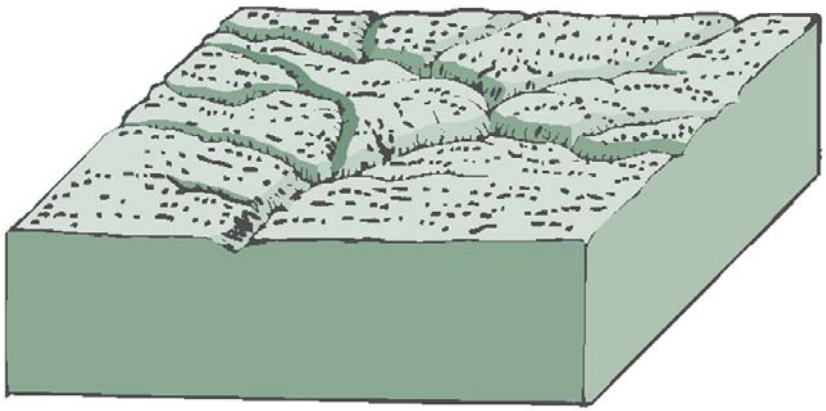
Raindrops sealing soil surface
Rainfall exceeding infiltration

EROSION RATE INCREASING ↓

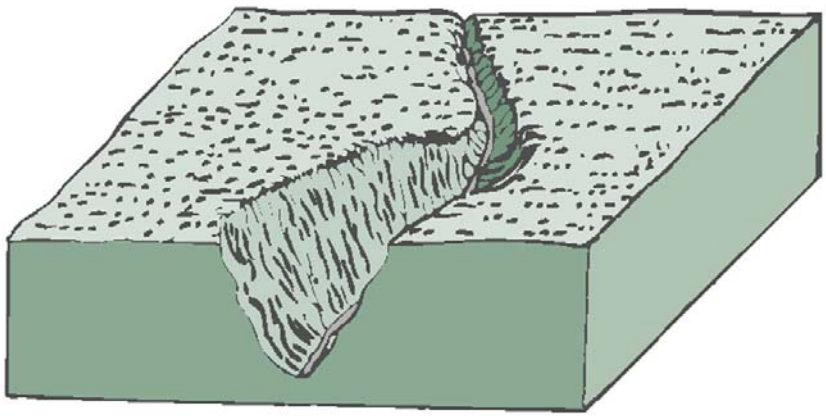
SHEET EROSION	**runoff in thin (a few mm) sheets**
RILL EROSION	**runoff in many small channels (rills), few mm wide & deep**
GULLY EROSION	**runoff in a single wide, deep channel**



(*a*) Sheet erosion



(*b*) Rill erosion



(c) Gully erosion

These factors have been built into the
UNIVERSAL SOIL LOSS EQUATION
(used to predict severity of erosion)

$$A = R \cdot K \cdot L \cdot S \cdot C \cdot P$$

A ≡ long-term average annual soil loss for a location

R ≡ long-term average rainfall-runoff erosivity factor

K ≡ Soil erodibility index (combines texture & structure factors)

L ≡ slope length factor

S ≡ slope angle factor

C ≡ soil cover factor

P ≡ erosion control practice factor (eg. contour tillage)

DEGRADATION CONTROL

Control of water erosion:

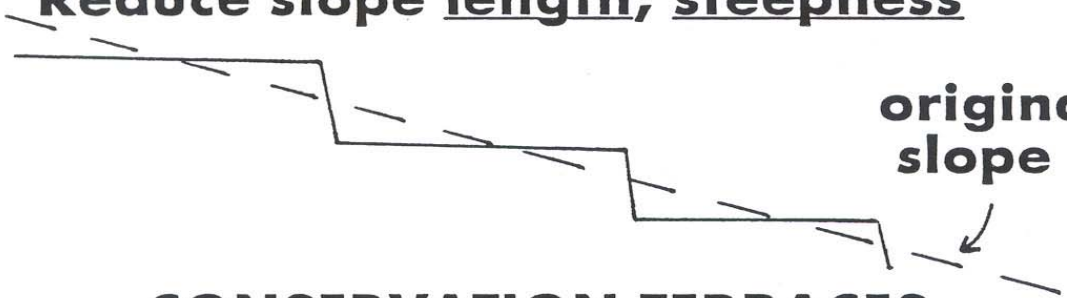
1. **COVER**

   - **intercepts raindrops**
   - **reduces runoff velocity**

   eg. mulch, living plants, artificial stabilizers

2. **MECHANICAL**

   Reduce slope length, steepness



CONSERVATION TERRACES

3. TILLAGE PRACTICES

- use cover to reduce runoff, erosion

GRASS WATERWAYS

natural or engineered channels planted permanently to grass

STRIP CROPPING

alternating strips of row crops and grass or legume, planted on the contour

CONSERVATION TILLAGE (NO-TILL)

leaves less bare soil
crop residue is left on soil surface

PROBLEMS: weed/disease/insect control
planting into residues

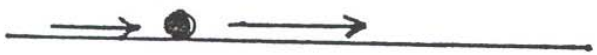
Wind Erosion

Air is a fluid, like water, so process is similar to that of water erosion

1

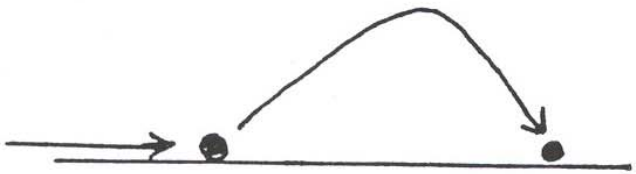
WIND FORCE < FORCE HOLDING PARTICLE

2



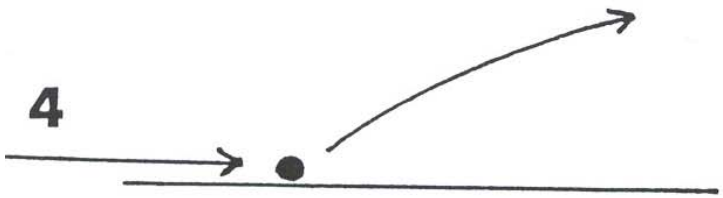
WIND FORCE > FORCE HOLDING PARTICLE

3



WIND FORCE > > FORCE HOLDING PARTICLE

4



WIND FORCE > > > HOLDING FORCE

UNIVERSAL WIND EROSION EQUATION -
$E = f(I, C, K, L, V)$

E ≡ potential average annual quantity of erosion

I ≡ soil erodibility (depends on particle size)

C ≡ local climate factor
(average wind velocity, average soil moisture)

K ≡ soil roughness
(rough surface resists erosion)

L ≡ "width of field"
(unprotected by wind barrier)

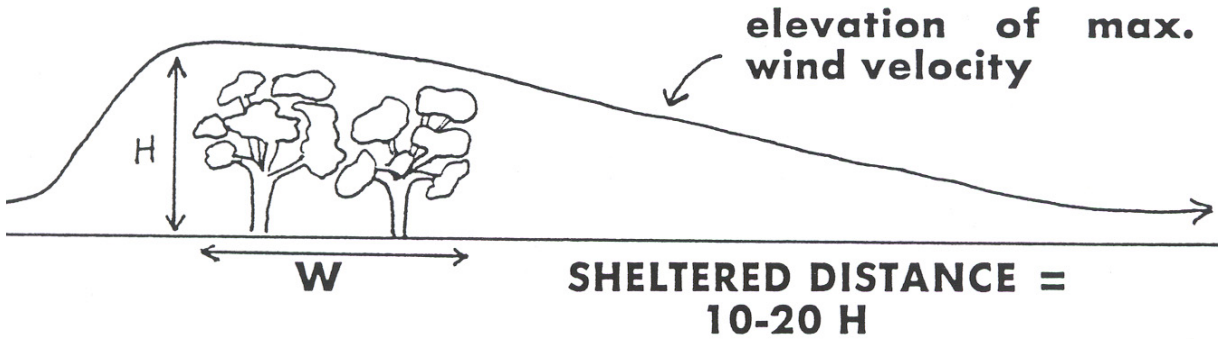
V ≡ quantity of vegetative cover

Control of wind erosion:

Modern agriculture has increased field size, lack of hedgerows or woodlots → WIND EROSION

Prevention Methods:

1. WINDBREAKS



Sheltered distance increases <u>somewhat</u> with W.

Usual windbreak - trees, shrubs

Poor windbreak - solid wall (wind turbulence on downwind side)

2. **Cover -**

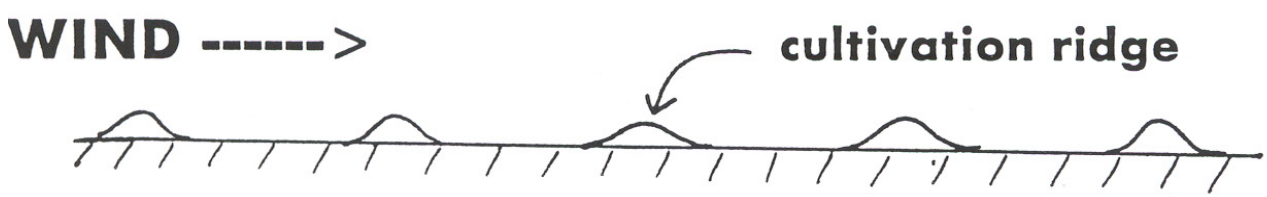
- **holds soil, increases surface roughness, preserves moisture**

- **holds snow, keeps soil more moist in spring.**

3. **Cultivation -**

- **increases surface roughness**

- **cultivate perpendicular to prevailing wind direction**




Loss of soil (Mg/ha/yr)
0
2
4
6
8
10
12
14
16
18
20
1982
1987
1992
1997
Sheet and rill
Wind

LESSON: Resources have limits

exploitation beyond those limits brings severe problems which may not be reversible.

Organic Soil Degradation -

Two problems notable in Histosols:

1. Wind Erosion

Promoted by - level terrain
- low bulk density of dry soil (0.1 - 0.3 g/cm^3)

Solution - strip cropping (eg. grain/asparagus)
- water management to keep surface moist

2. Microbial Decomposition

Lowered water table aerates soil:
organic matter ---> energy + CO_2 + H_2O
Soil thickness decreases rapidly

Solution? Flood soil between crops

Other Problems

Desertification -

Change from arid agricultural land to desert

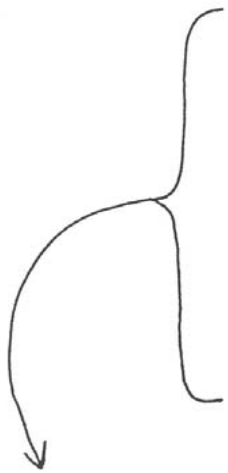
Removal of vegetation accelerates erosion

Suggested reasons for process:

Natural - brought about by climate change

Poor management -

- overgrazing
- overcultivation
- poor irrigation practices
- deforestation
- burning of all animal manure, vegetation for fuel



Loss in fertility, soil cover

CONTROL OF PHYSICAL DEGRADATION

Three methods to lessen compaction:

1) **reduce machinery weight**

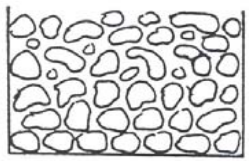
2) **reduce number of trips the machinery makes (minimum tillage)**

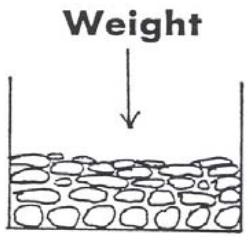
3) **keep off soil when it is wet**

Compaction can be reversed by special deep tillage methods.

Crusting can be reduced by:

light cultivation
adding gypsum ($CaSO_4$)
mulches





UNCOMPACTED
(BULK DENSITY = 1.3g/cm^3)

COMPACTED
(BULK DENSITY = 1.6)

Compaction

- **restricts water flow**
- **impedes root extension**
- **occurs <u>easily</u> in wet soils (less friction)**