15

17

Soil Erosion and Its Control

The wind crosses the brown land, unheard . . .
—*T. S. Eliot,* The Waste Land

Soil Erosion

(Chapter 17)

- Soils formation adds about 1 cm every 100-400 years. That is about 0.3-1.3 tonnes/hectare/year
- Rates of natural erosion vary but are on average about 1 t/ha/yr
- Rates of accelerated erosion due to landuse practices commonly exceed 10 t/ha/yr and sometimes exceed 100 t/ha/yr.

For example:

- ➢ Loess plateau of China > 200 t/ha/yr
- ➢ Himalayan foothills of Nepal > 200 t/ha/yr
- ➢ In India, gully erosion results in a loss of 8000 ha of land per year.
- ➢ In US it is estimated that nationally the annual costs of soil erosion are:
  - ✓ On-site: 40 million
  - ✓ Off-site: 17 billion (communication systems, flooding, siltation of waterways, property damage.) Fish, recreation.

- Remediation:
  - ➢ Agronomic
  - ➢ Management
  - ➢ Mechanical

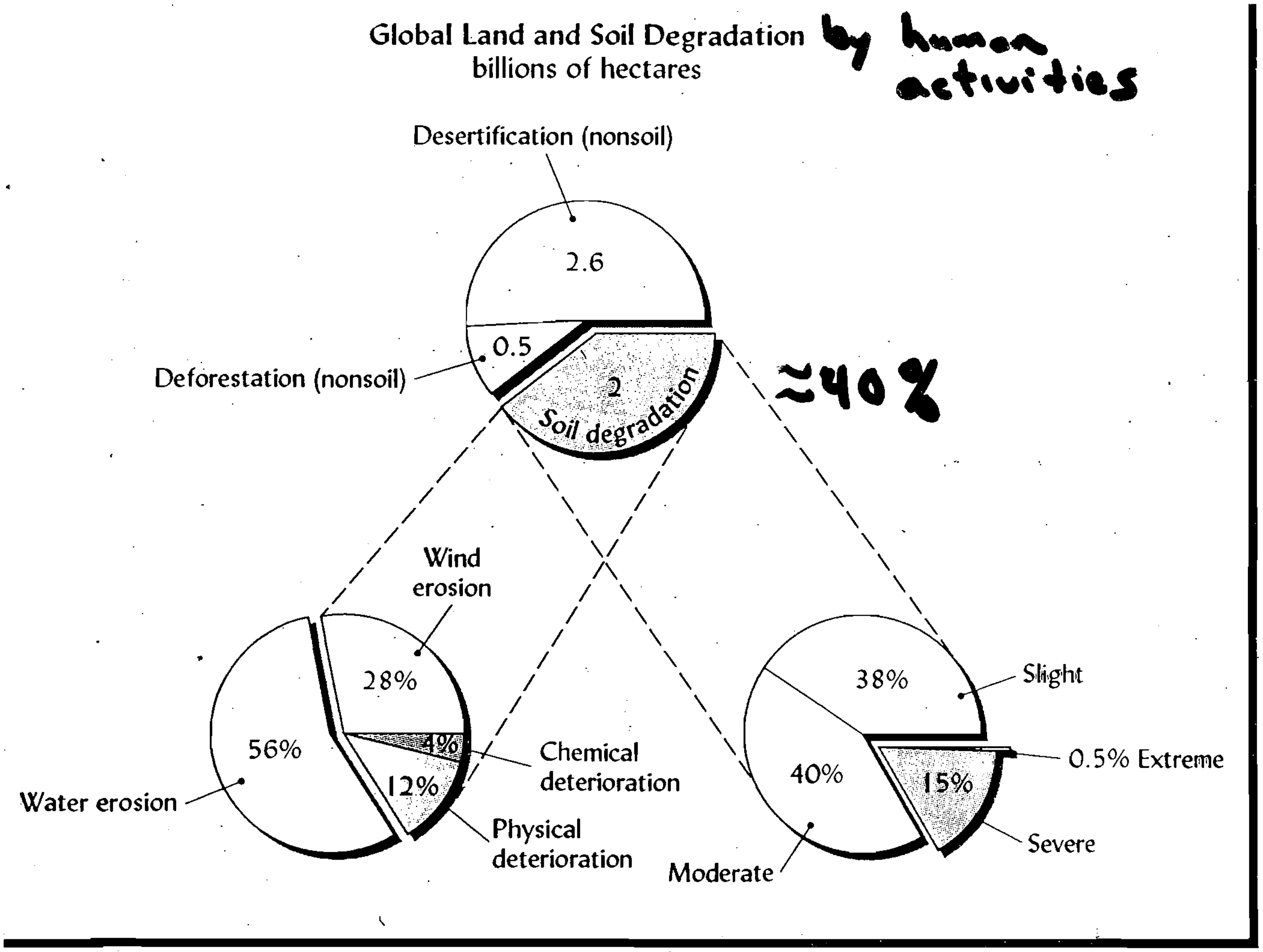


FIGURE 17.1 Soil degradation as a part of global land degradation caused by overgrazing, deforestation, inappropriate agricultural practices, fuel wood overexploitation, and other human activities. About 60% of degraded land has not suffered soil degradation. Of the 2 billion ha of land with degraded soils, most could be restored easily (*slight* degradation) or with considerable financial and technical investments (*moderate* degradation). *Severely* degraded soils are currently useless for agriculture and would require major international assistance for restoration. About 9 million ha (0.5% of degraded soils) are *extremely* degraded and incapable of restoration. About 85% of the soil degradation is caused by erosion by wind and water. [FAO data selected from Oldeman (1994) and Daily (1997)]

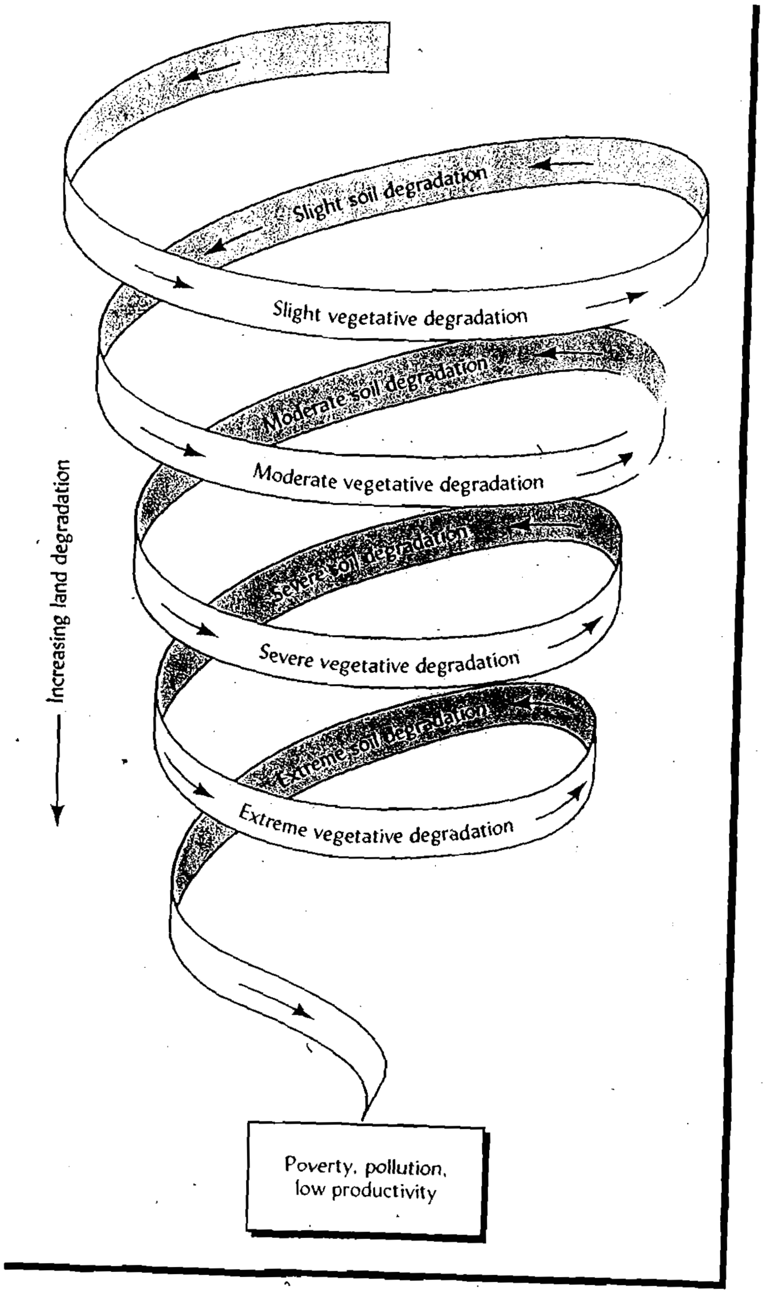


FIGURE 17.2 The downward spiral of lanc degradation resulting from the feedback looj between soil and vegetative degradation.

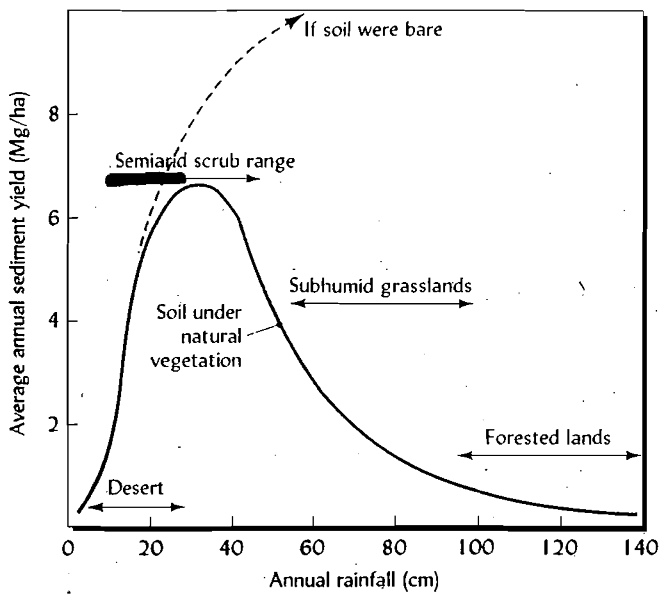


FIGURE 17.3 Generalized relationship between annual rainfall and soil loss from geologic erosion by water. The actual amount of sediment lost annually per hectare will depend on other climatic variables, topography, and the type of soils in the watershed. Note that sediment yields are greatest in semiarid regions. Here a number of severe runoff–generating storms occur in most years, but the total rainfall is too little to support much protective plant cover. By comparison, the very dry deserts have too little rain to cause much erosion, and the well-watered regions support dense forests that effectively protect the soil. Where the natural vegetation is destroyed by plowing, erosion from the bare soils is much higher with increasing rainfall, as indicated by the dashed curve.

FIGURE 17.5 Erosion and deposition occur simultaneously across a landscape. (Left) The soil on this ridgetop was worn down by erosion during nearly 300 years of cultivation. The surface soil exposed on the ridgetop consists mainly of light-colored C horizon aterial. At sites lower down the slope the surface horizon shows mainly A and B horizon material, some of which has been posited after eroding from locations upslope. (Right) Erosion on the sloping wheat field in the background has deposited a thick layer of sediment in the foreground, burying the plants at the foot of the hill. [Photos courtesy of R. Weil (left) and USDA Natural Resources Conservation Service (right)]

river sediments

(a)

(b)

Dredging $

FIGURE 17.6 Off-site damages caused by soil erosion include the effects of sediment on aquatic systems. (*a*) A sediment-laden tributary stream empties into the relatively clear waters of a larger river. The turbid water will foul fish gills, inhibit submerged aquatic vegetation, and clog water-purification systems. Part of the sediment will settle out on the river bottom, covering fish-spawning sites and raising the river bed enough to aggravate the severity of future flooding episodes. (*b*) Expensive dredging and excavation (by the dragline in the foreground) is being undertaken to restore the beauty, recreational value, and flood-control function of this pond in a neighborhood park after accumulated sediment had transformed it into a mere mudflat. The watershed upstream from the pond had undergone a period of rapid suburban development, during which adequate sediment-control practices were not used on the construction sites. [Photos courtesy of USDA Natural Resources Conservation Service (*a*) and R. Weil (*b*)]

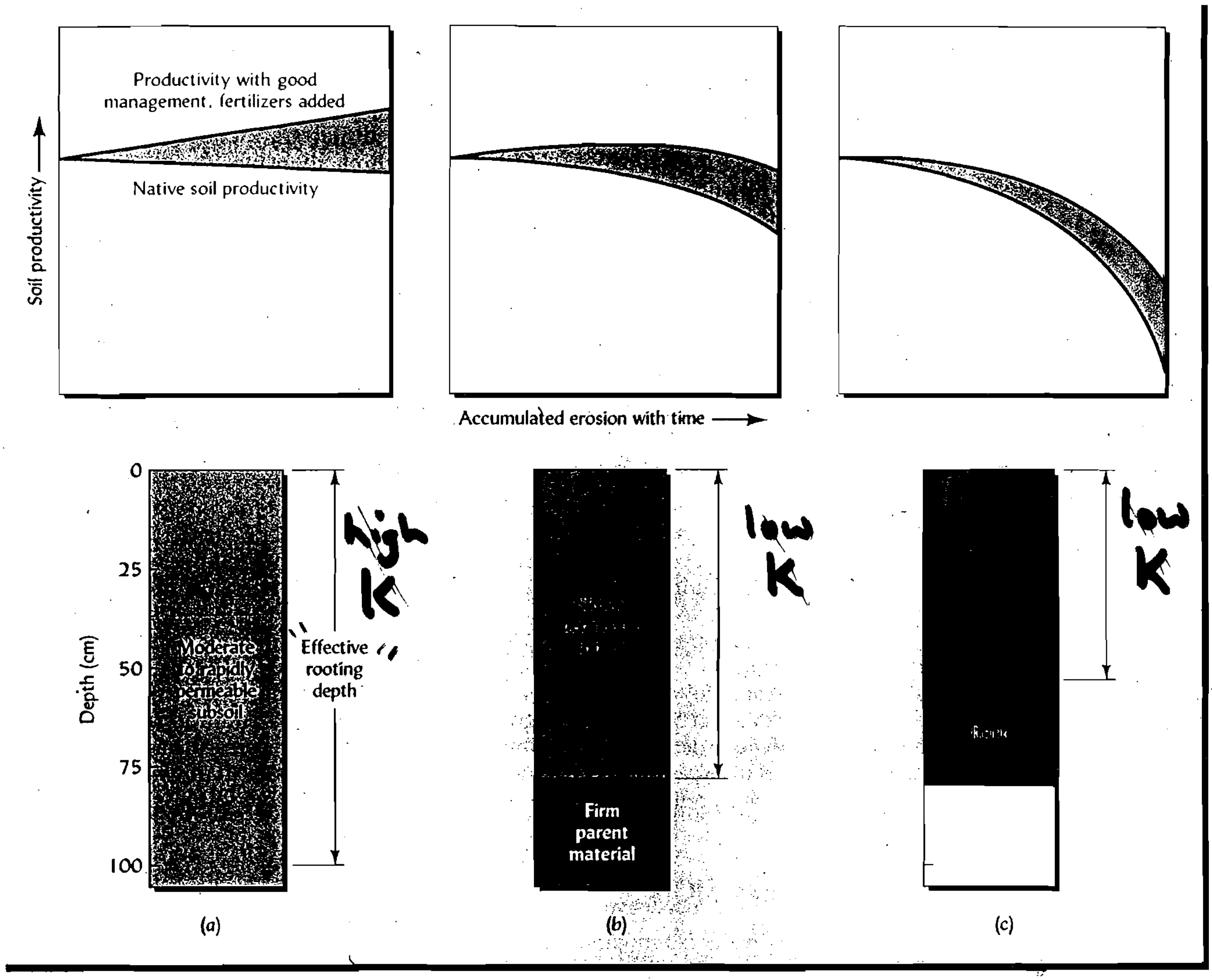


FIGURE 17.7 Effect of erosion over time on the productivity of three soils differing in depth and permeability. Productivity on soil (*a*) actually increases with time because of good management practices and fertilizer additions, even though the native soil productivity declines as a result of erosion. Because soil (*c*) is shallow and has restricted permeability, its productivity declines rapidly as a result of erosion, a decline that good management and fertilizers cannot prevent. Soil (*b*), which is intermediate in both depth and permeability, suffers only a slight decline in productivity due to erosion. Soil characteristics clearly influence the effect of erosion on soil productivity.

Universal Soil Loss Equation:

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

A = Mean Annual Soil Loss

R = rainfall erosivity index - based on long term rainfall conditions specific to the area, intensity, seasonal distribution.

K = soil erosivity index
- based on texture, organic matter, permeability

L = slope length

S = slope steepness

C = cropping factor (relative to bare soil)

P = conservation practice factor (contouring, strip-cropping)

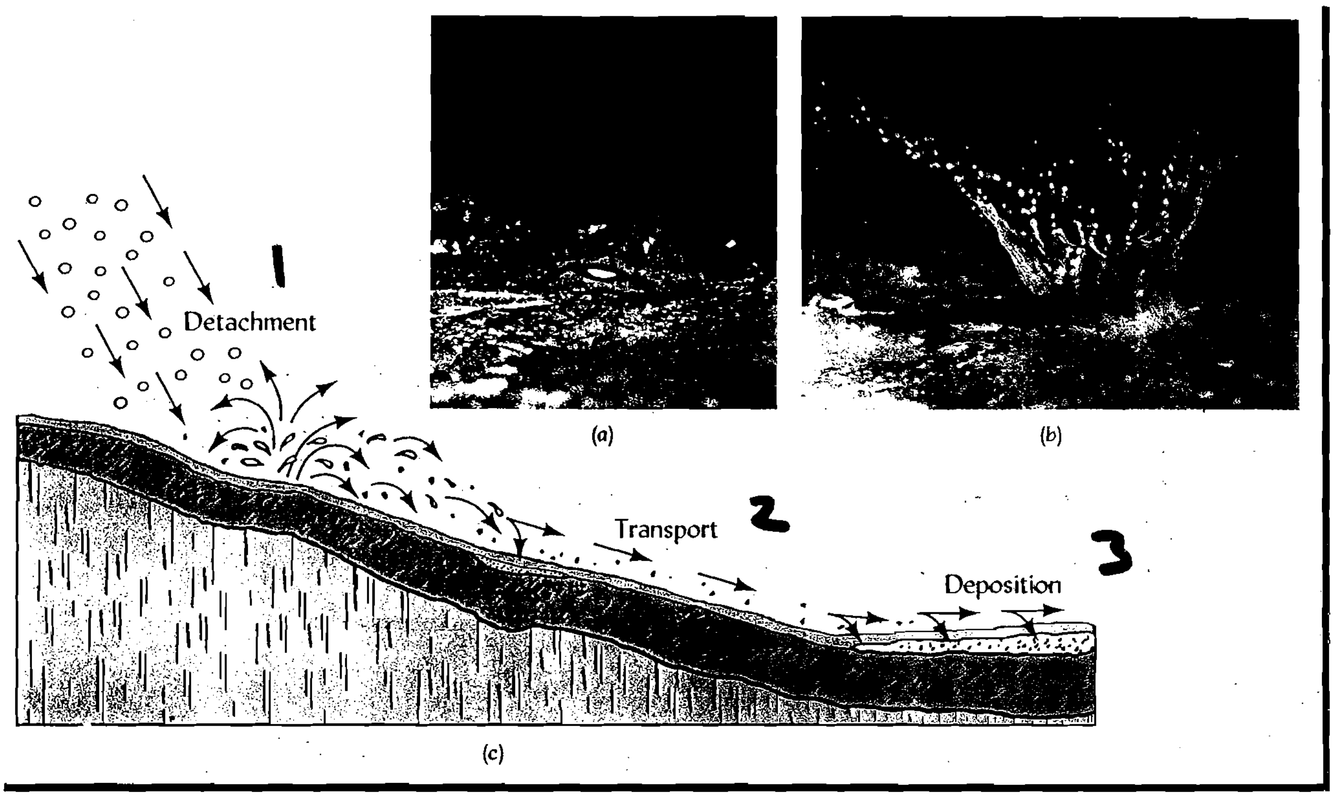
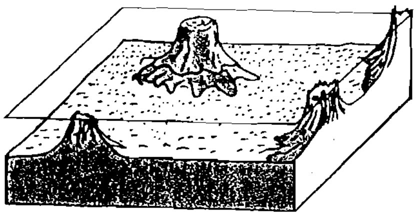
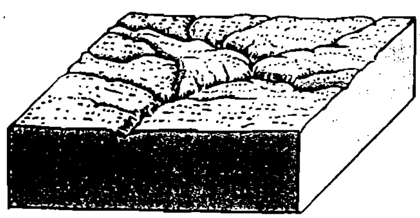


FIGURE 17.8 The three-step process of soil erosion by water begins with the impact of raindrops on wet soil. (*a*) A raindrop speeding toward the ground. (*b*) The splash that results when the drop strikes a wet, bare soil. Such raindrop impact destroys soil aggregates, encouraging sheet and interill erosion. Also, considerable soil may be moved by the splashing process itself. The raindrop affects the detachment of soil particles, which are then transported and eventually deposited in locations downhill (*c*).

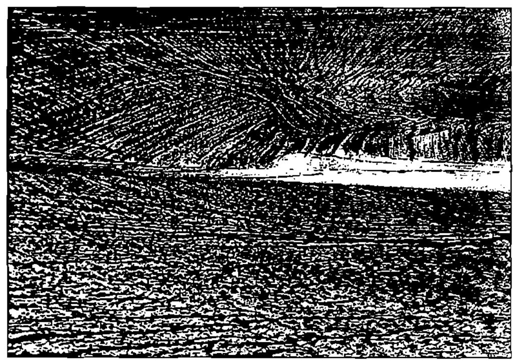


(*a*) Sheet erosion

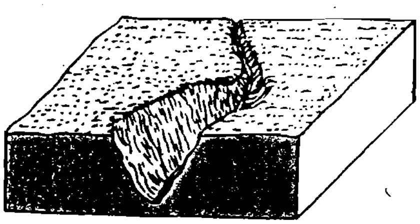
Sheet erosion



(*b*) Rill erosion



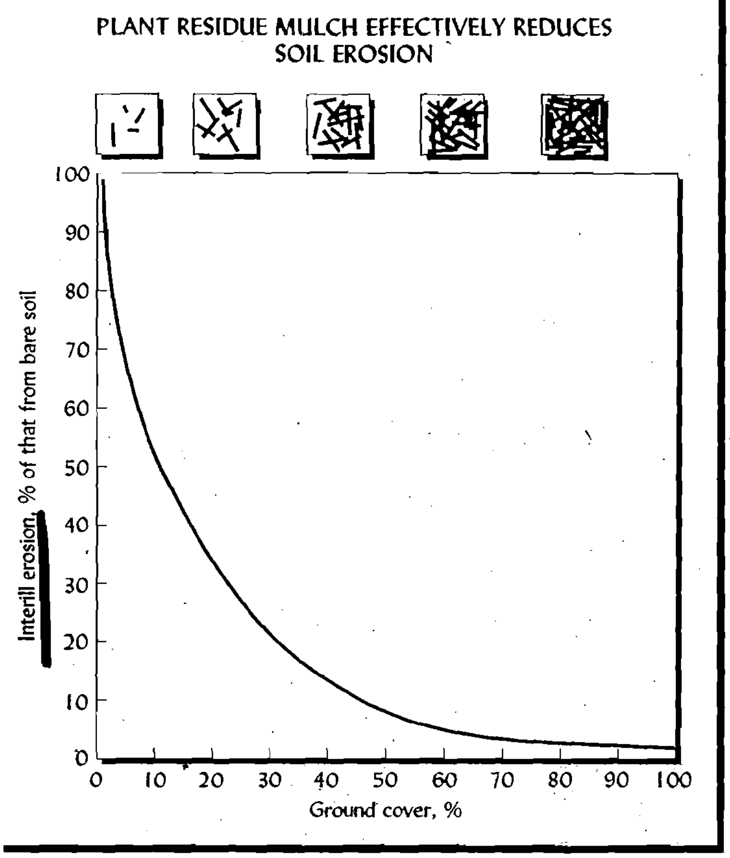
Rill



(*c*) Gully erosion

Gully

FIGURE 17.9 Three major types of soil erosion. *Sheet erosion* is relatively uniform erosion from the entire soil surface. Note that the perched stones and pebbles have protected the soil underneath from sheet erosion. The pencil gives a sense of scale. *Rill erosion* is initiated when the water concentrates in small channels (rills) as it runs off the soil. Subsequent cultivation may erase rills, but it does not replace the lost soil. *Gully erosion* creates deep channels that cannot be erased by cultivation. Although gully erosion looks more catastrophic, far more total soil is lost by the less obvious sheet and rill erosion. [Drawings from FAO (1987); photos courtesy USDA Natural Resources Conservation Service]



inter-rill erosion

FIGURE 17.11 Reduction in interrill erosion achieved by increasing ground cover percentage. The diagrams above the graph illustrate 5, 20, 40, 60, and 80% ground cover. Note that even a light covering of mulch has a major effect on soil erosion. The graph applies to interrill erosion. On steep slopes, some rill erosion may occur even if the soil is well covered. [Generalized relationship based on results from many studies]

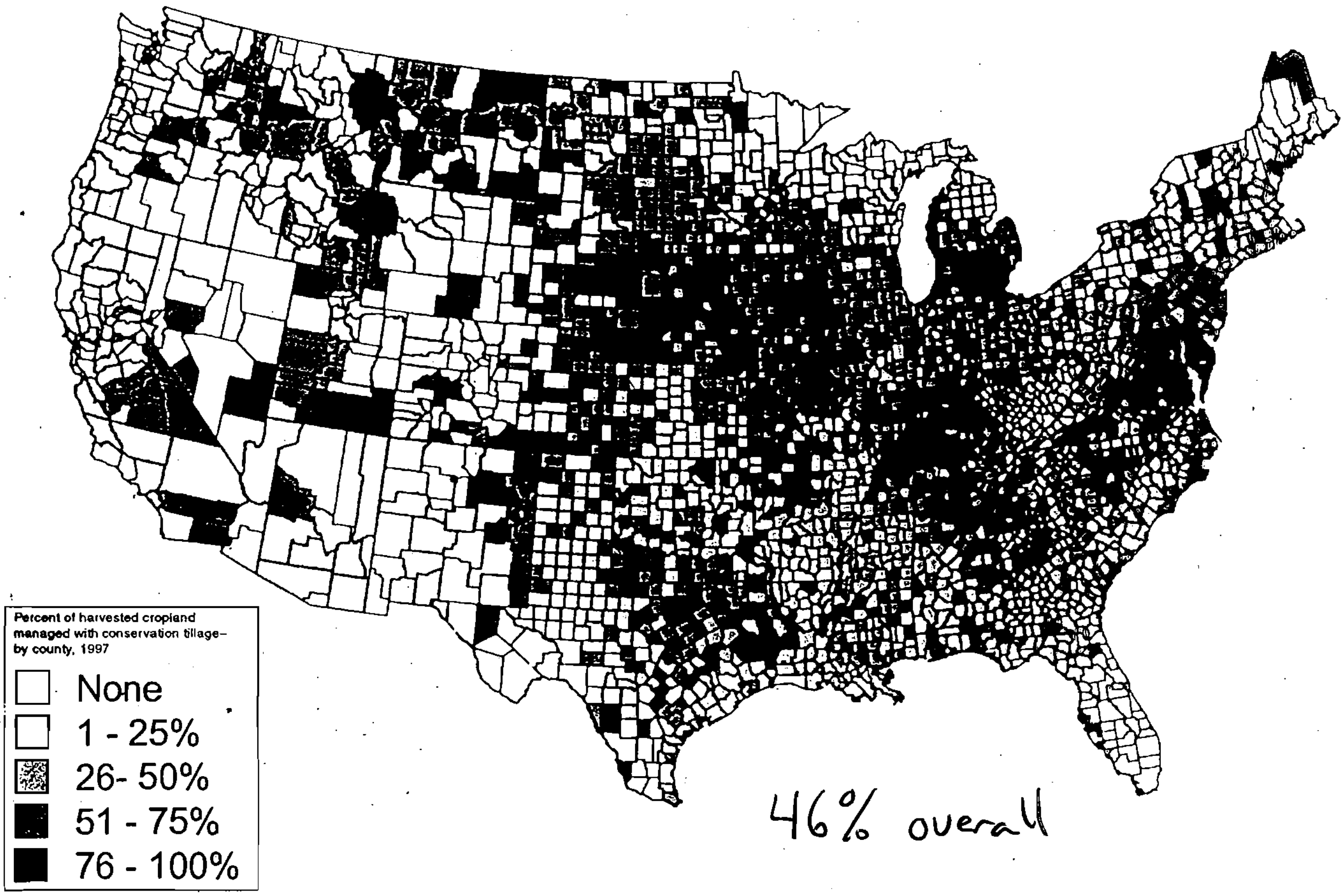


FIGURE 17.17 The percentage use of conservation tillage on different areas of the United States in 1997. Note that in some areas more than three-fourths of the cropland is managed using these soil-saving systems. Overall, some 46% of cropland hectares were managed with conservation tillage. (Courtesy Conservation Technology Information Center, West Lafayette, Ind.)

Conservation Tillage

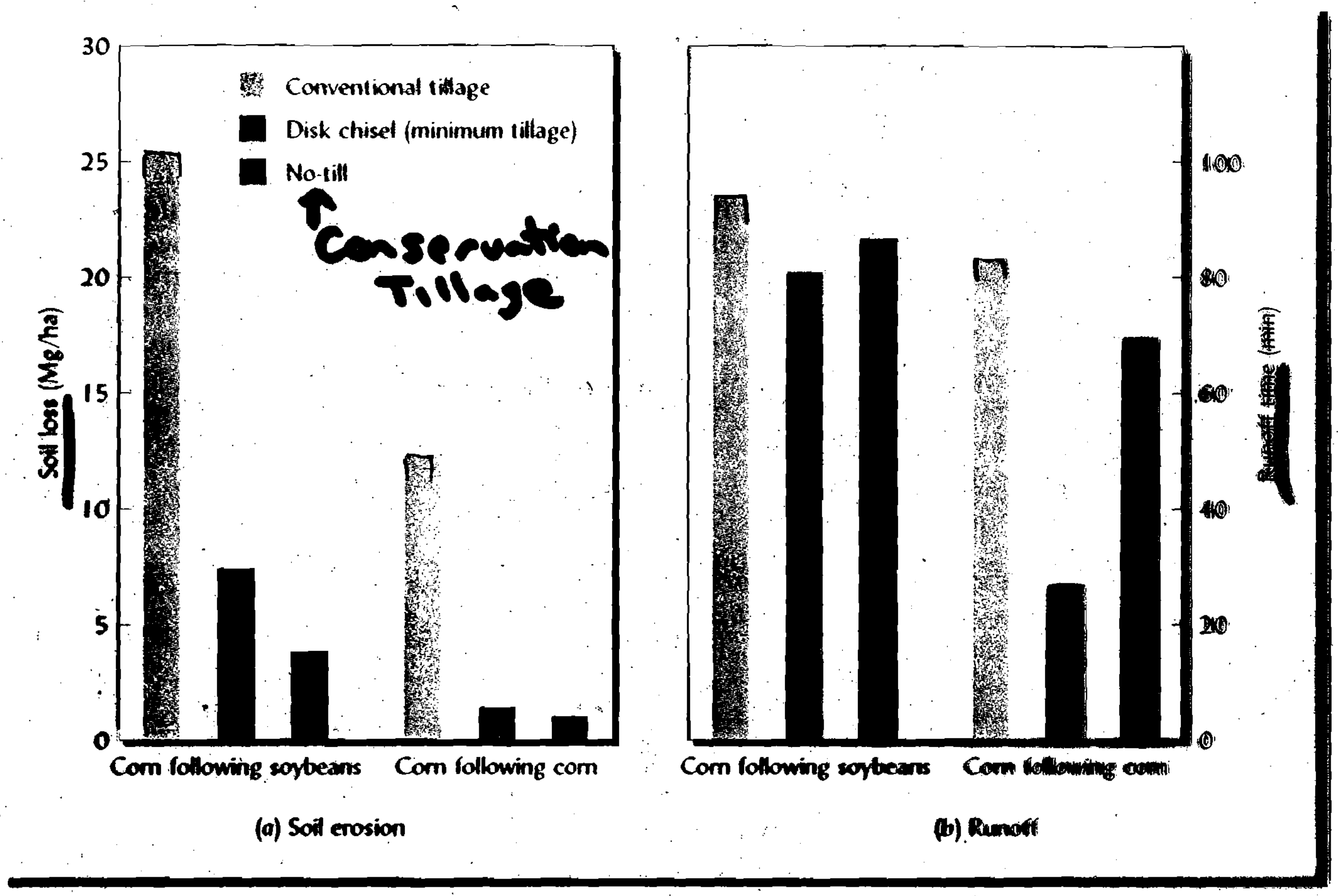


FIGURE 17.18 Effect of tillage systems on soil erosion and runoff from corn plots in Illinois following corn and following soybeans. Soil loss by erosion was dramatically reduced by the conservation tillage practices. The period of runoff was reduced most by the disk chisel system where corn was grown after corn. The soil was a Typic Argiudoll (Catlin silt loam), 5% slope, planted up- and downslope, tested in early spring. [Data from Oschwald and Siemens (1976)]

-period of runoff reduced ~~reduced~~ most with chisel plow.

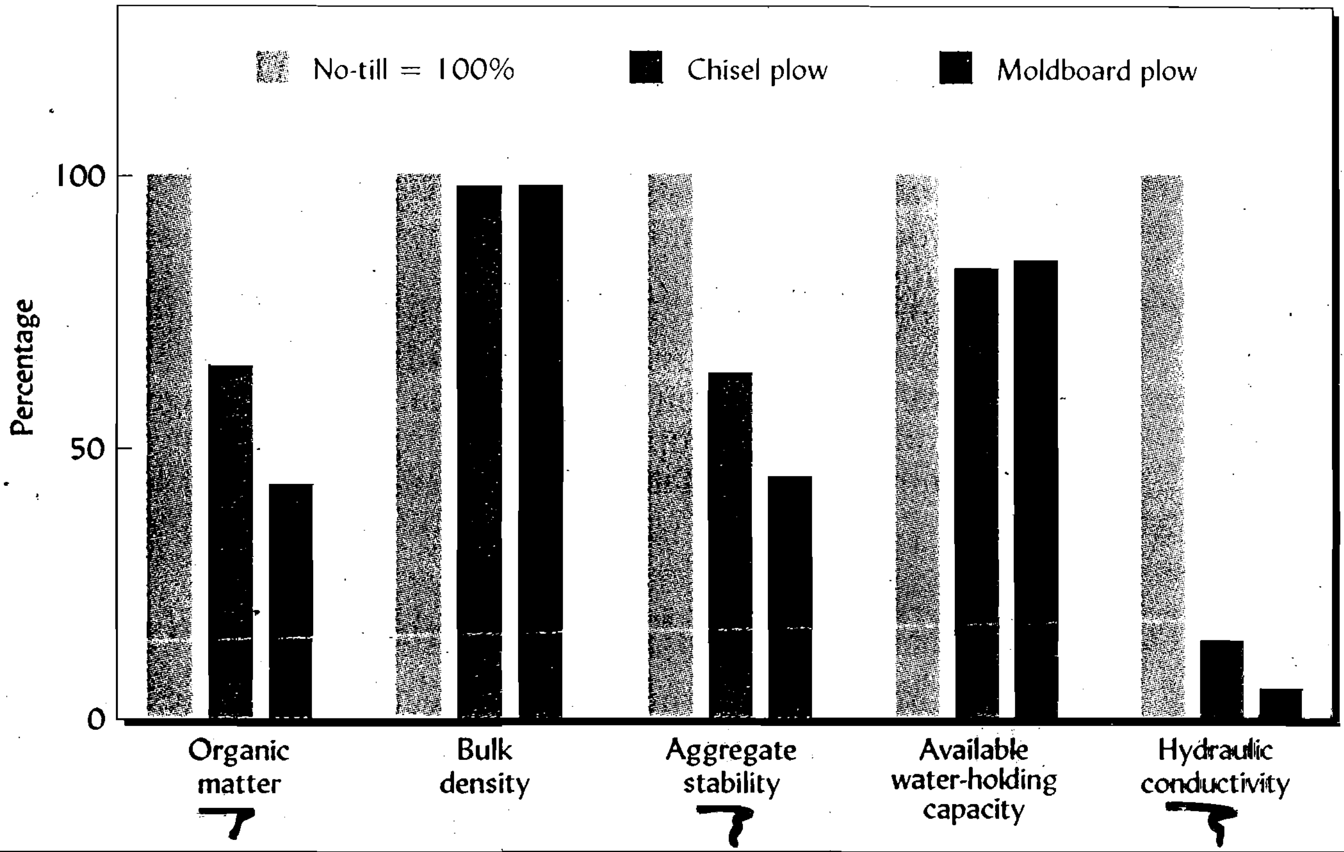


FIGURE 17.19 The comparative effects of 28 years of three tillage systems on soil organic matter content and a number of soil physical properties of an Alfisol in Ohio. Values for the no-till system were taken as 100, and the others are shown in comparison. Bulk density was about the same for each tillage system, but for all other properties the no-till system was decidedly more beneficial than either of the other two systems. The saturated hydraulic conductivity was especially high with no-till. [From Mahboubi, et al. (1993); used with permission of the Soil Science Society of America]

Gully erosion

FIGURE 17.21 The devastation of gully erosion. (Upper) Gully erosion in action on a highly erodible soil in western Tennessee. The roots of the small wheat plants are powerless to prevent the cutting action of the concentrated water flow. (Lower) The legacy of neglect of human-induced accelerated erosion. Tillage of sloping soils during the days of the Roman Empire began a process of accelerated erosion that eventually turned swales into jagged gullies that continue to cut into this Italian landscape with each heavy rain. For a sense of scale, note the olive trees and houses on the grassy, gentle slopes of the relatively uneroded hilltops. (Upper photo courtesy of the USDA Natural Resources Conservation Service, lower photo courtesy of R. Weil)

Legacy of Poor Soil Management During Roman Empire

Wind erosion

Dust Storm

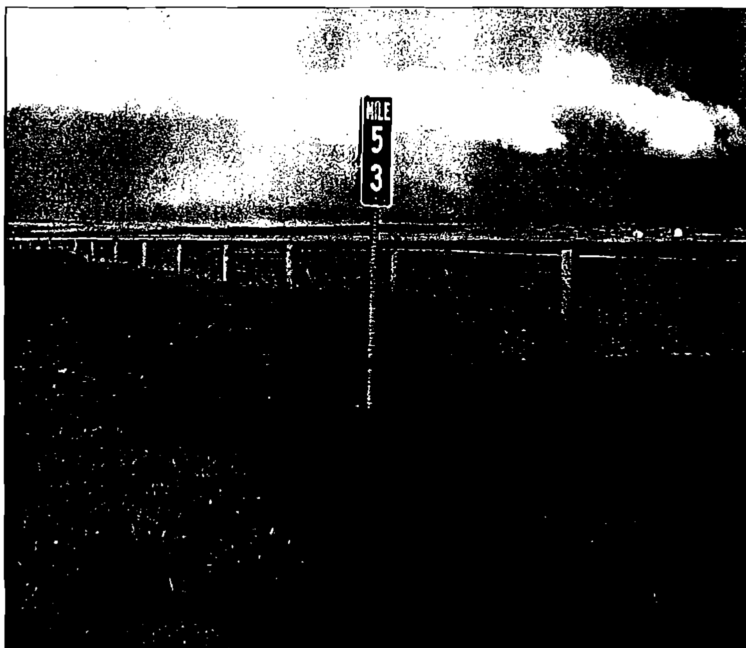


FIGURE 17.30 Wind erosion in action. (Upper) One result of wind erosion is dust storms, such as this one moving across the high plains of Texas. The swirling dark cloud consists of fine particles eroded from the soil by high winds sweeping across the flat farmland and range. Apparently, most of the land was not as well covered with vegetation as the wheat field in the foreground. (Lower) Soil eroded by wind during a single dust storm has piled up to a depth of nearly 1 m along a fencerow in Idaho. (Upper photo courtesy of Dr. Chen Weinan, USDA Agricultural Research Service, Warm Springs, Tex.; lower photo courtesy of R. Weil)

Soil Deposited by wind.

Wind Erosion → Saltation process

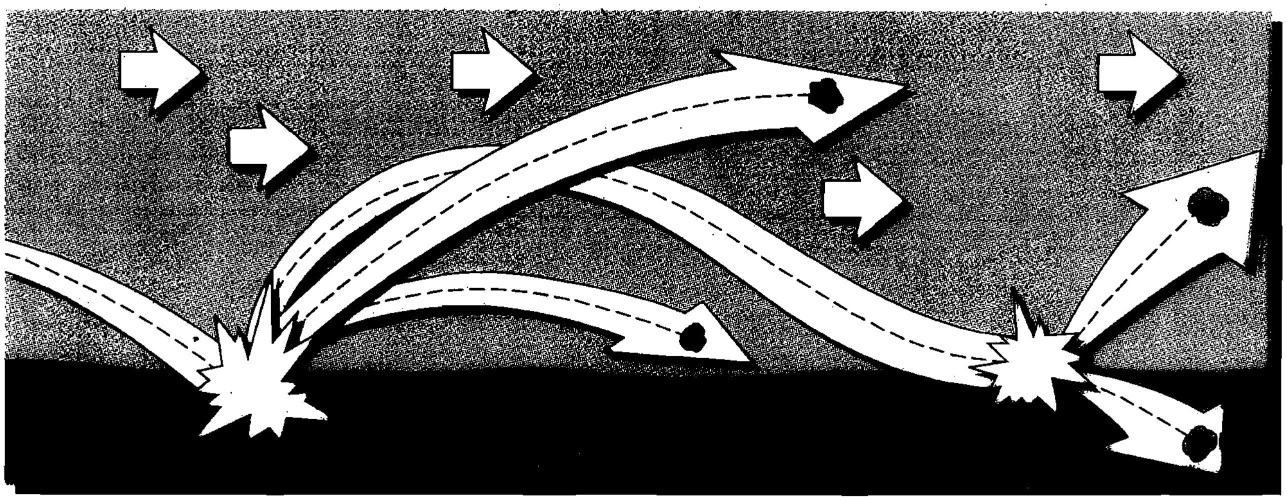


FIGURE 17.32 The process of saltation. Medium-sized particles (0.05 to 0.5 mm in diameter) bounce along the soil surface, striking and dislodging other particles as they move. They are too large to be carried long distances suspended in the air but small enough to be transported by the wind. [From Hughes (1980); used with permission of Deere & Company, Moline, Ill.]