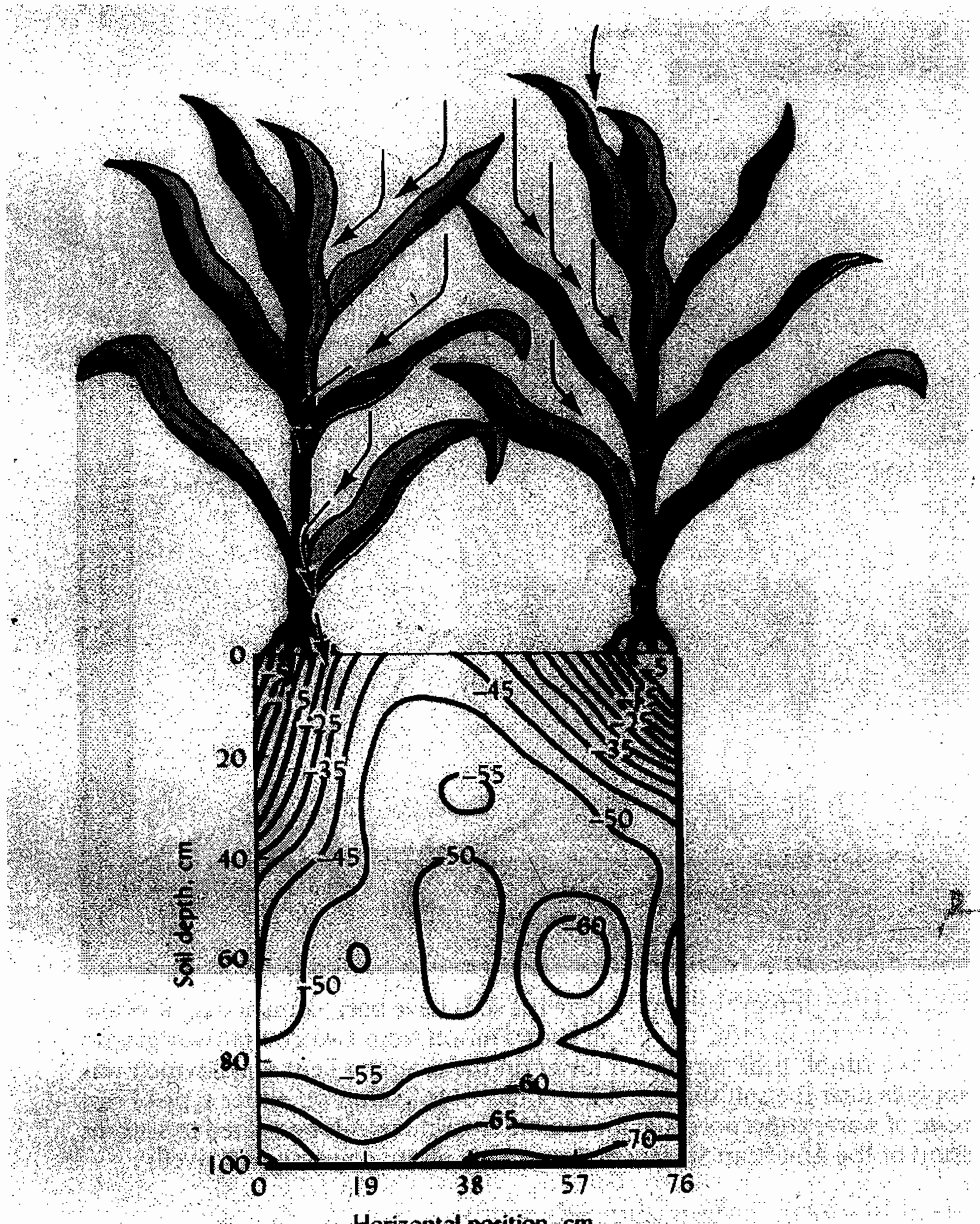
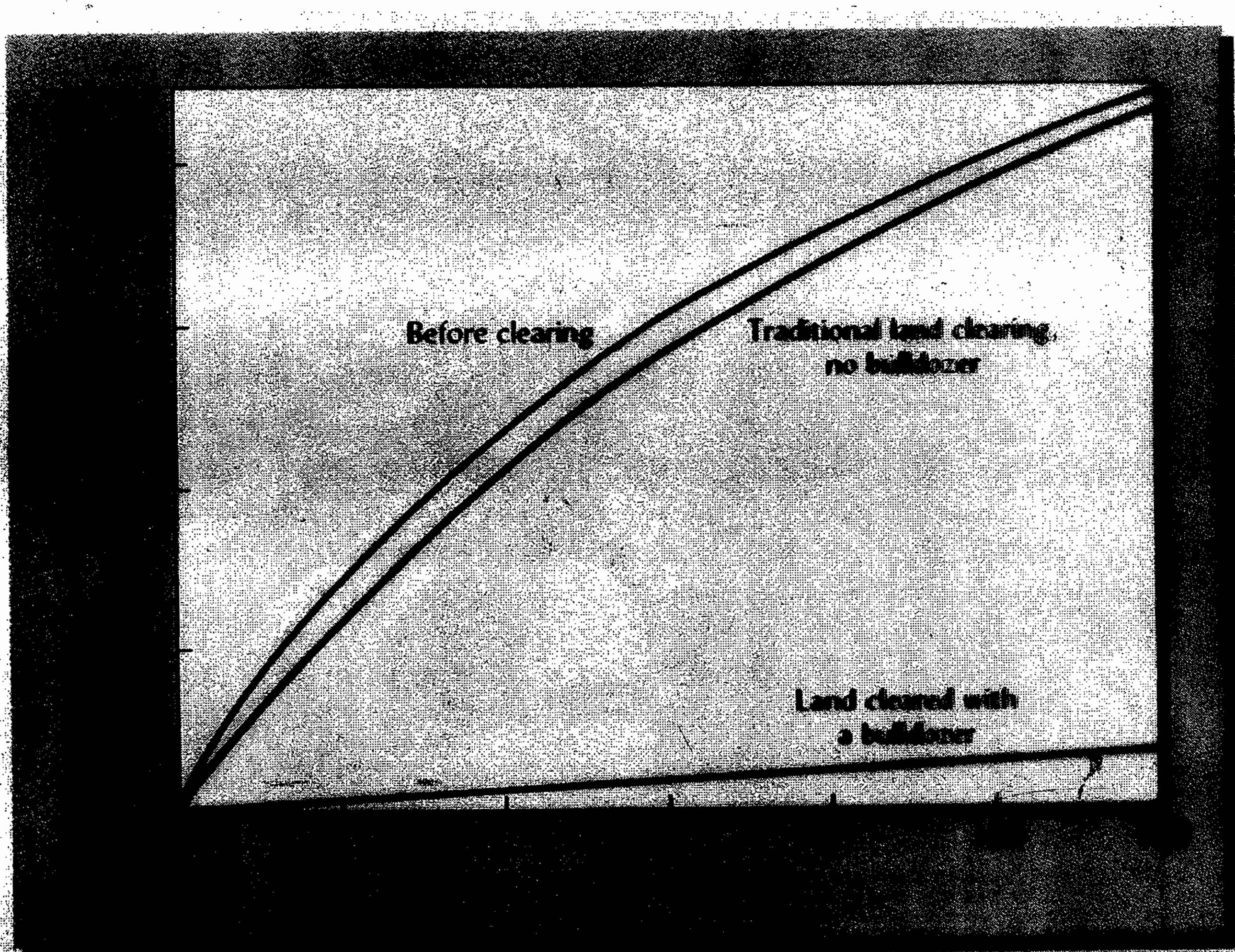
6

SOIL AND THE HYDROLOGIC CYCLE

Both soil and water belong to the biosphere, to the order of nature, and—as one species among many, as one generation among many yet to come—we have no right to destroy them.

—DANIEL HILLEL, *OUT OF EARTH*


-45
-55
-50
-50
-60
-55
-60
-65
-70
-45
-50
-35
-25
Soil depth, cm
0
20
40
60
80
100
0
19
38
57
76
Horizontal position, cm


Before clearing
Traditional land clearing, no bulldozer
Land cleared with a bulldozer

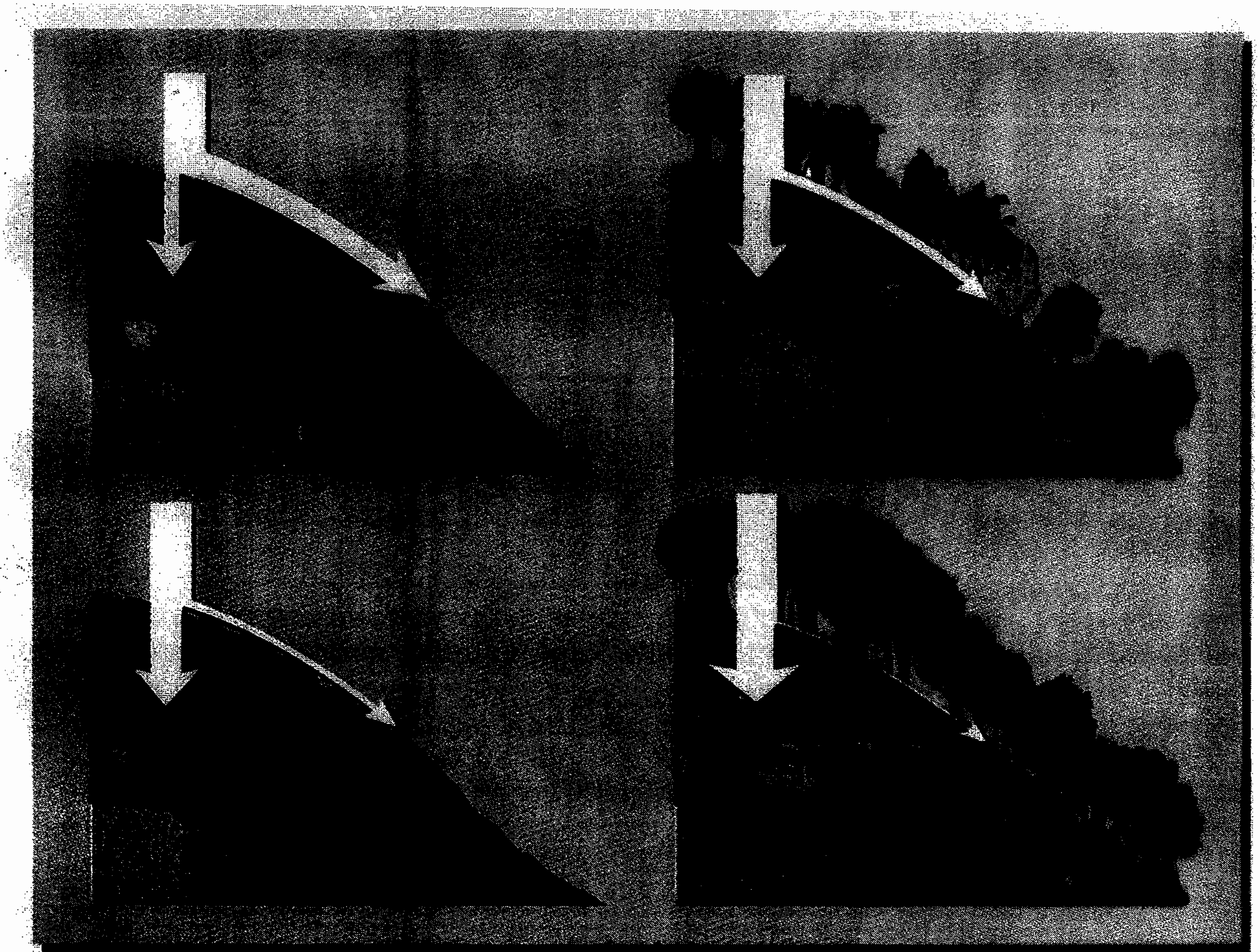


FIGURE 6.9 Influence of soil structure and vegetation on the partitioning of rainfall into infiltration and runoff. The upper two diagrams show soils with tight, unstable structure that resists infiltration and

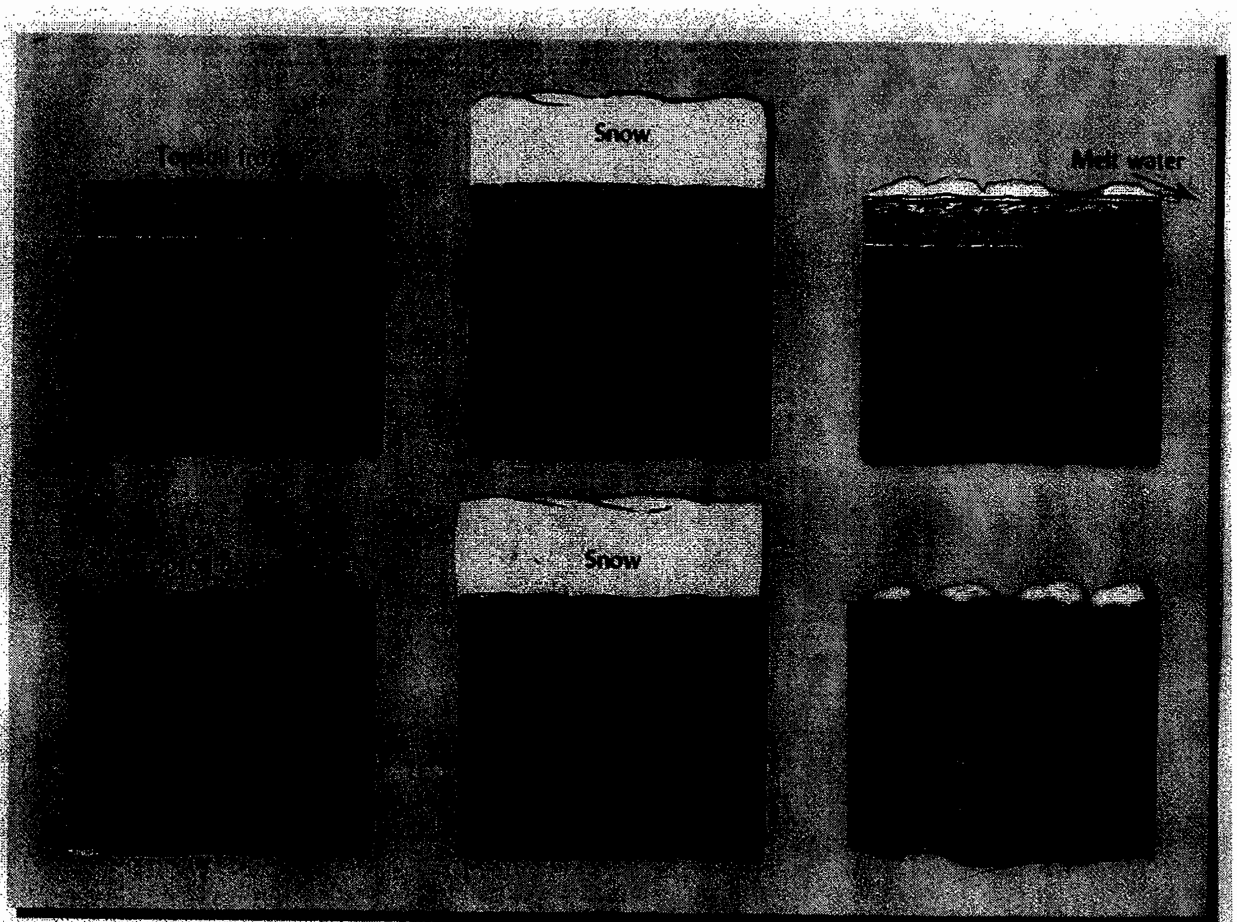


FIGURE 6.4 The relative timing of freezing temperatures and snowfall in the fall in some temperate regions drastically influences water runoff and infiltration into soils in the spring. The upper three diagrams illustrate what happens when the surface soil freezes before the first heavy snowfall. The snow insulates the soil so that it is still frozen and impermeable as the snow melts in the spring. The lower sequence of diagrams illustrates the situation when the soil is unfrozen in the fall when it is covered by the first deep snowfall.

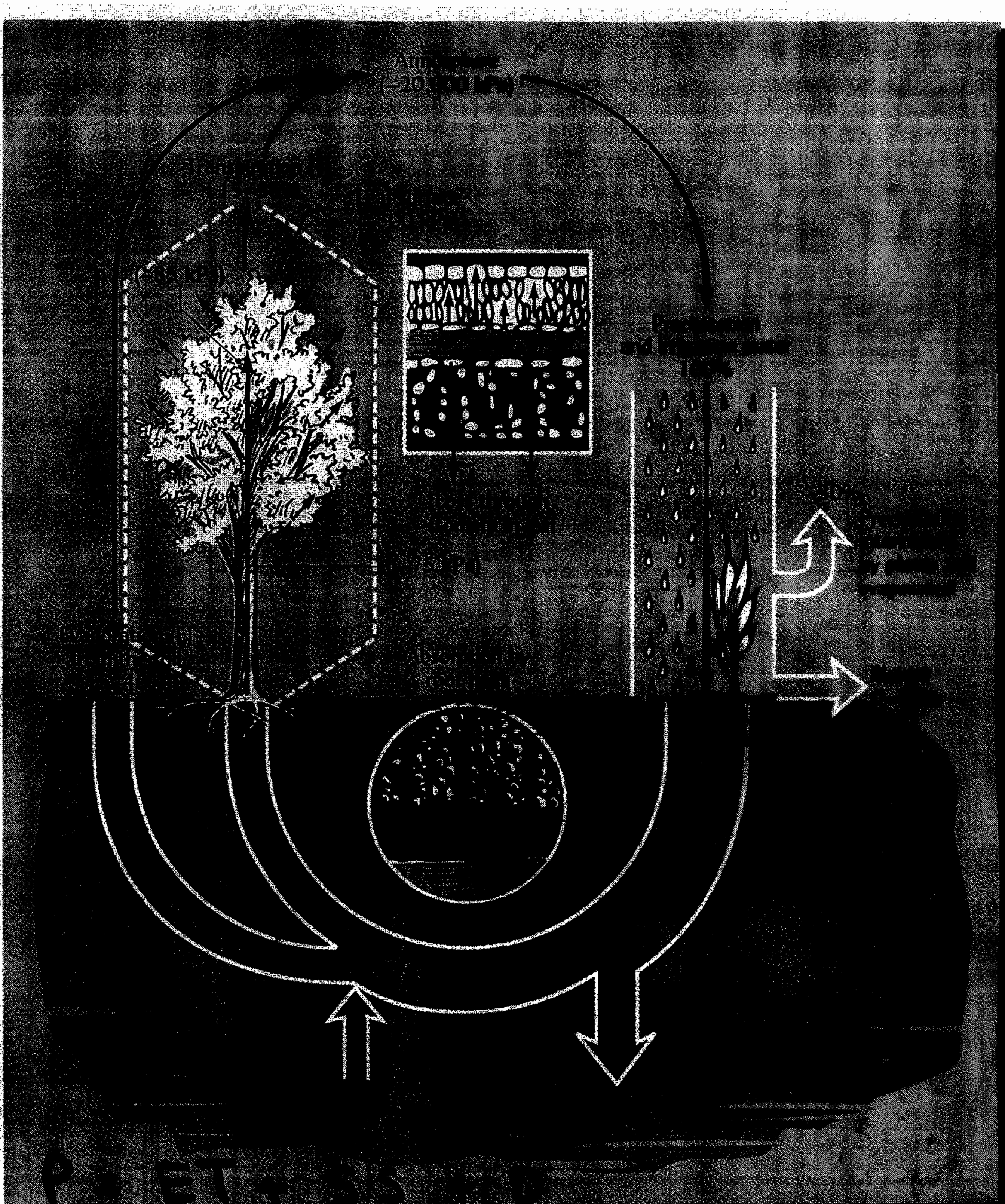


FIGURE 6.10 Soil–plant–atmosphere continuum (SPAC) showing water movement from soil to plants to the atmosphere and back to the soil in a humid to subhumid region. Water behavior through the continuum is subject to the same energy relations covering soil water that were discussed in Chapter 5. Note that the moisture potential in the soil is –50 kPa, dropping to –70 kPa in the root, declining still further as it moves upward in the stem and into the leaf, and is very low (–500 kPa) at the leaf–atmosphere interface, from whence it moves into the atmosphere where the moisture potential is –20,000 kPa. Moisture moves from a higher to lower moisture potential. Note the suggested ranges for partitioning of the precipitation and irrigation water as it moves through the continuum.

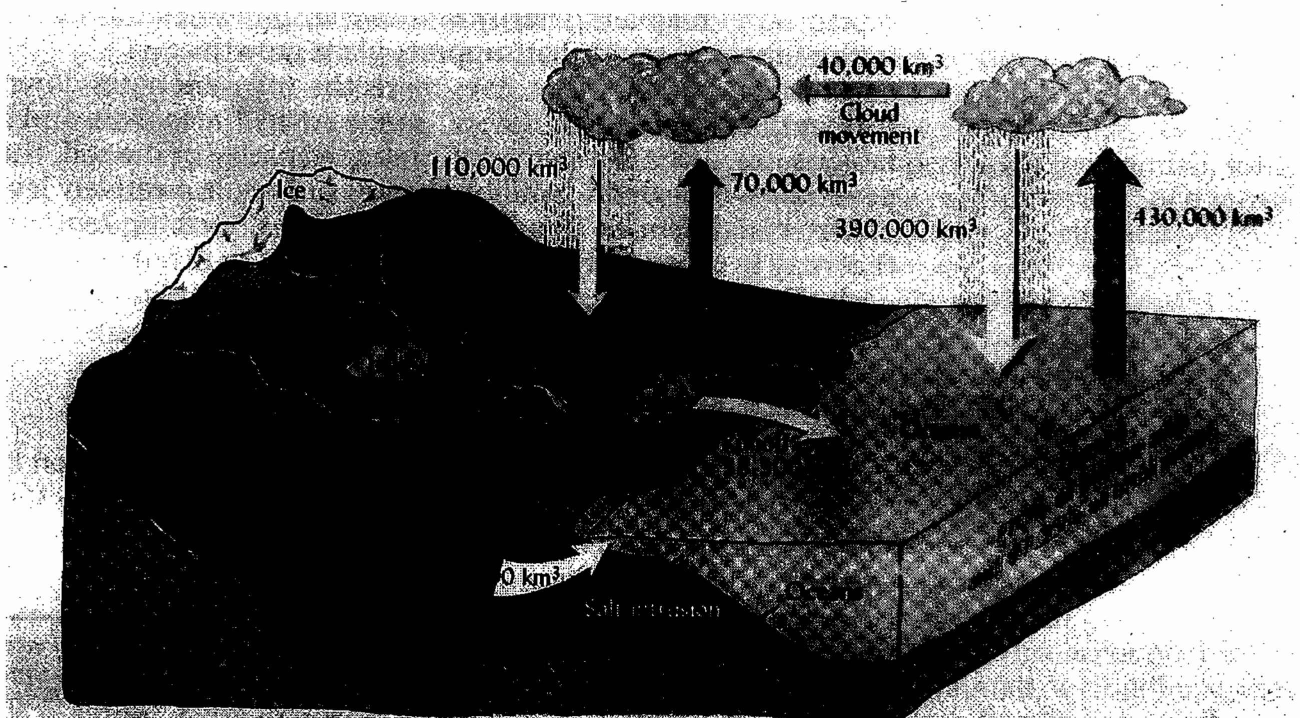
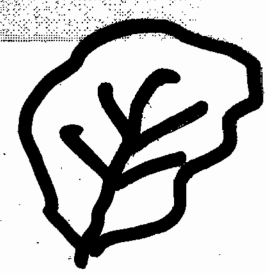
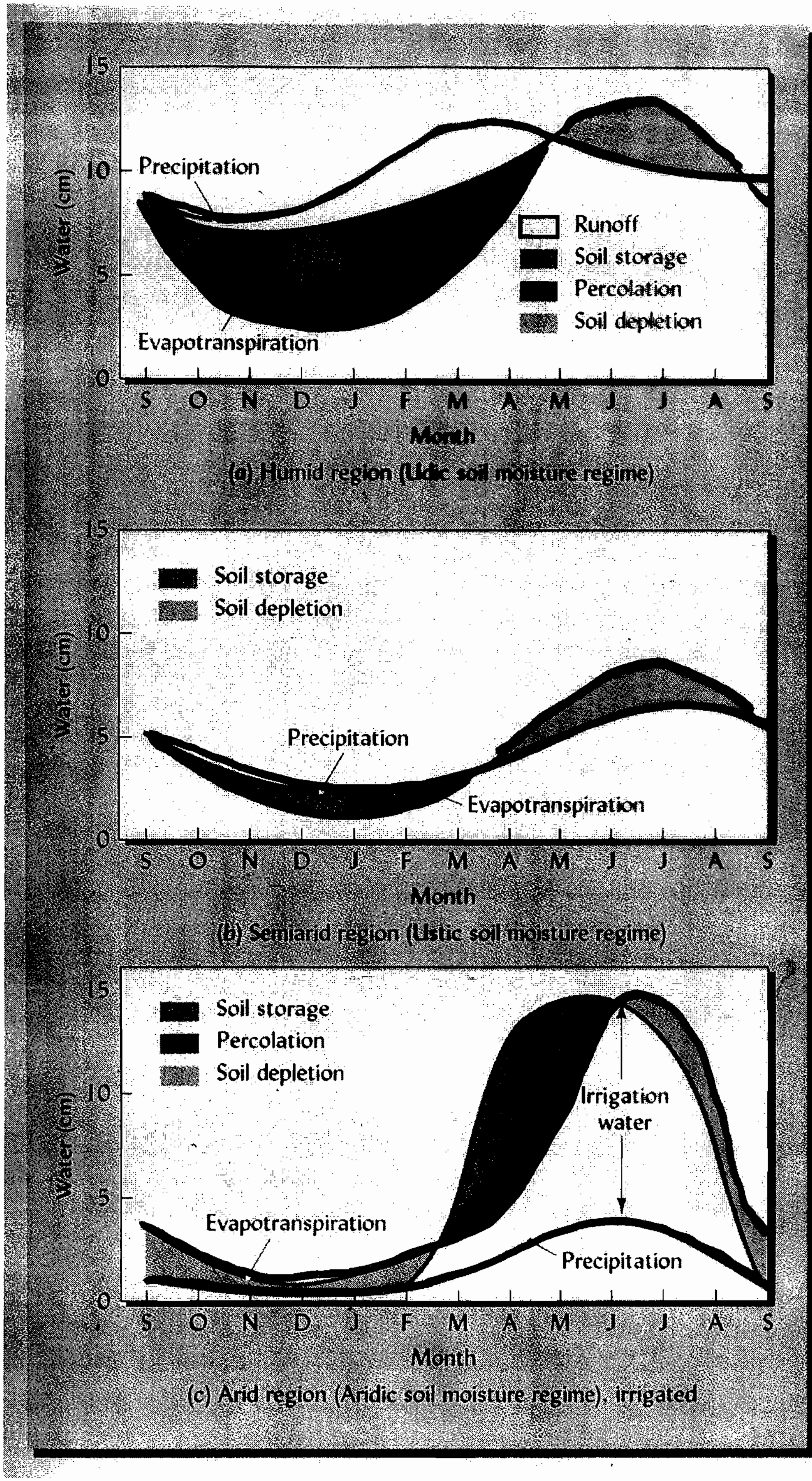


FIGURE 6.2 The hydrologic cycle upon which all life depends is very simple in principle. Water evaporates from the earth's surface, both the oceans and continents, and returns in the form of rain or snowfall. The net movement of clouds brings some 40,000 km^3 of water to the continents and an equal amount of water is returned through runoff and groundwater seepage that is channeled through rivers to the ocean. About 86% of the evaporation and 78% of the precipitation occurs in the ocean areas. However, the processes occurring on land areas where the soils are influential have impacts not only on humans but on all other forms of life, including those residing in the sea.

Watershed
or
Catchment



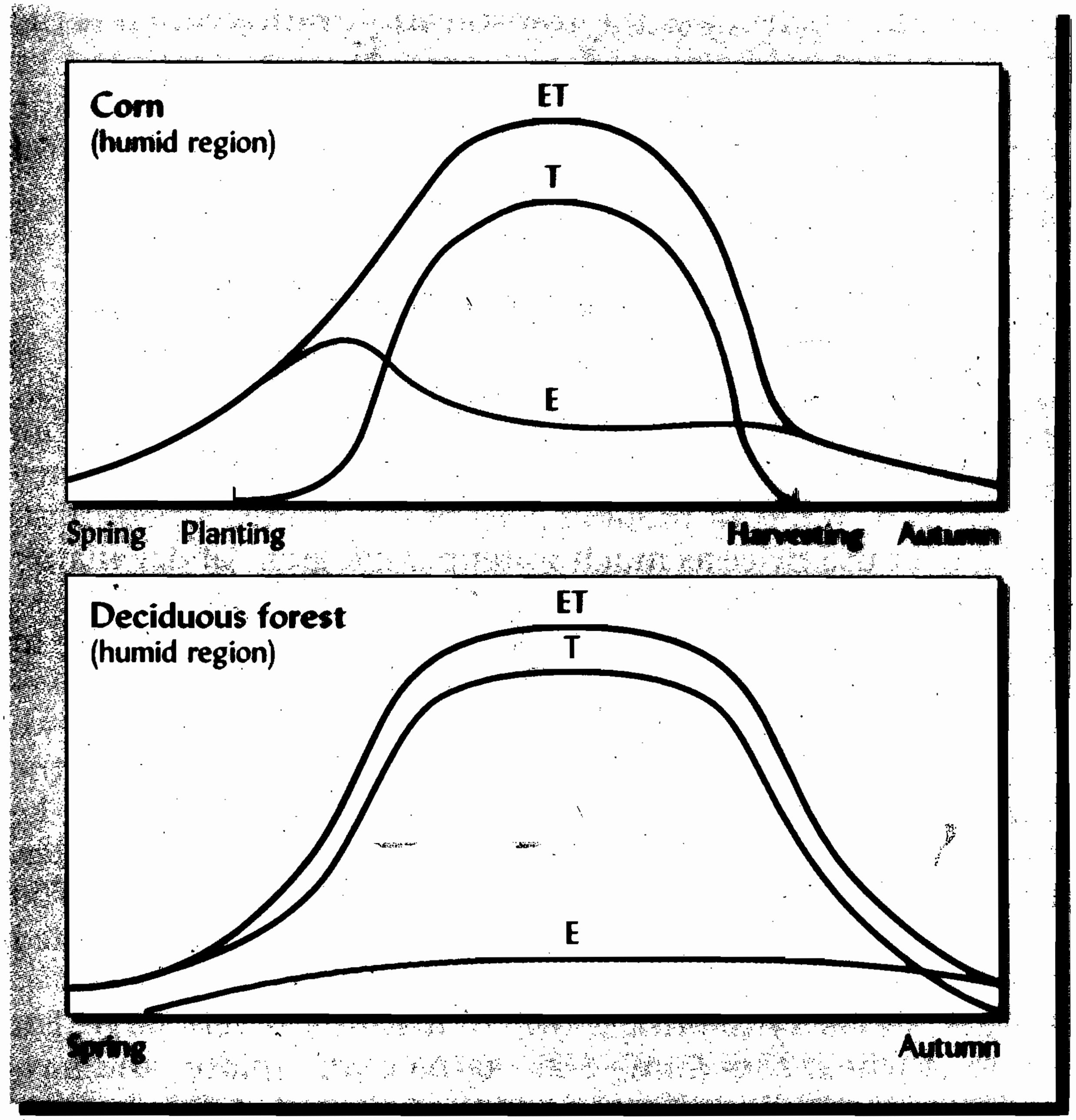


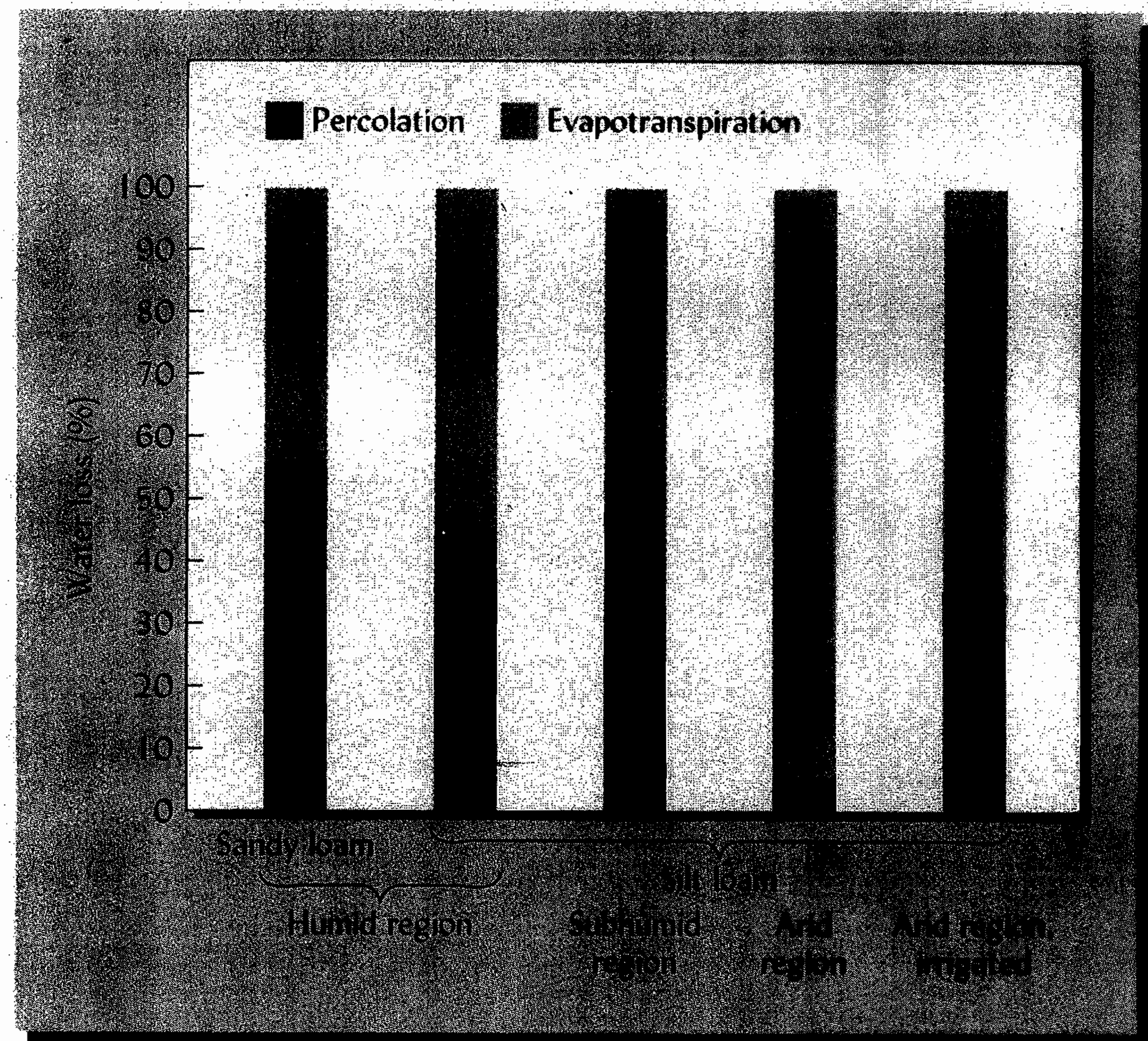
(a) Humid region (Udic soil moisture regime)

(b) Semiarid region (Ustic soil moisture regime)

(c) Arid region (Aridic soil moisture regime), irrigated

$P = ET + SS + D$


Corn
(humid region)
ET
T
E
Spring
Planting
Harvesting
Autumn
Deciduous forest
(humid region)
ET
T
E
Spring
Autumn



Percolation
Evapotranspiration
Water loss (%)
100
90
80
70
60
50
40
30
20
10
0
Sandy loam
Silt loam
Humid region
Subhumid region
Arid region
Arid region, irrigated

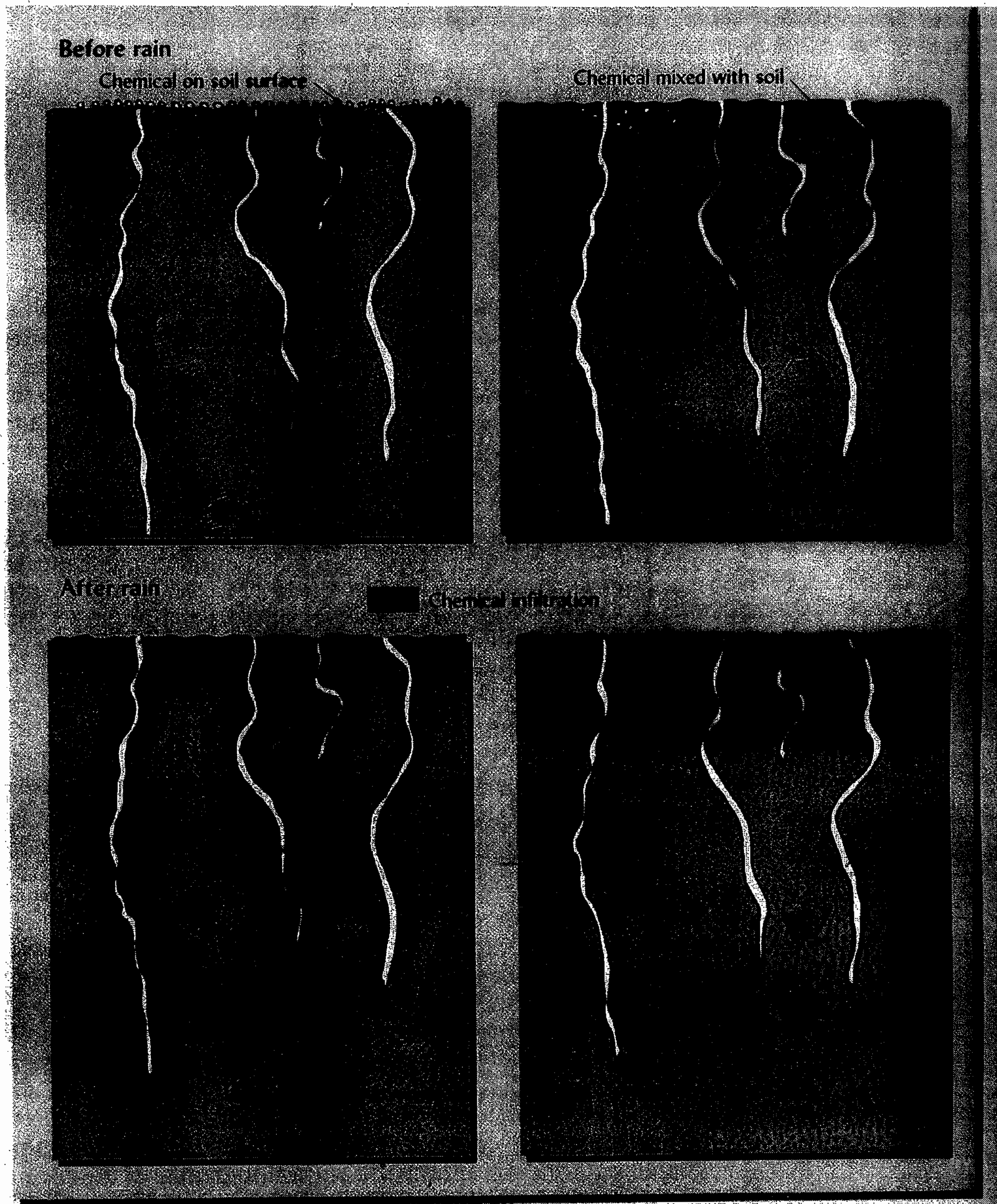


FIGURE 6.25 Preferential or bypass flow in macropores transports soluble chemicals downward through a soil profile. Where the chemical is on the soil surface (left), and can dissolve in surface-

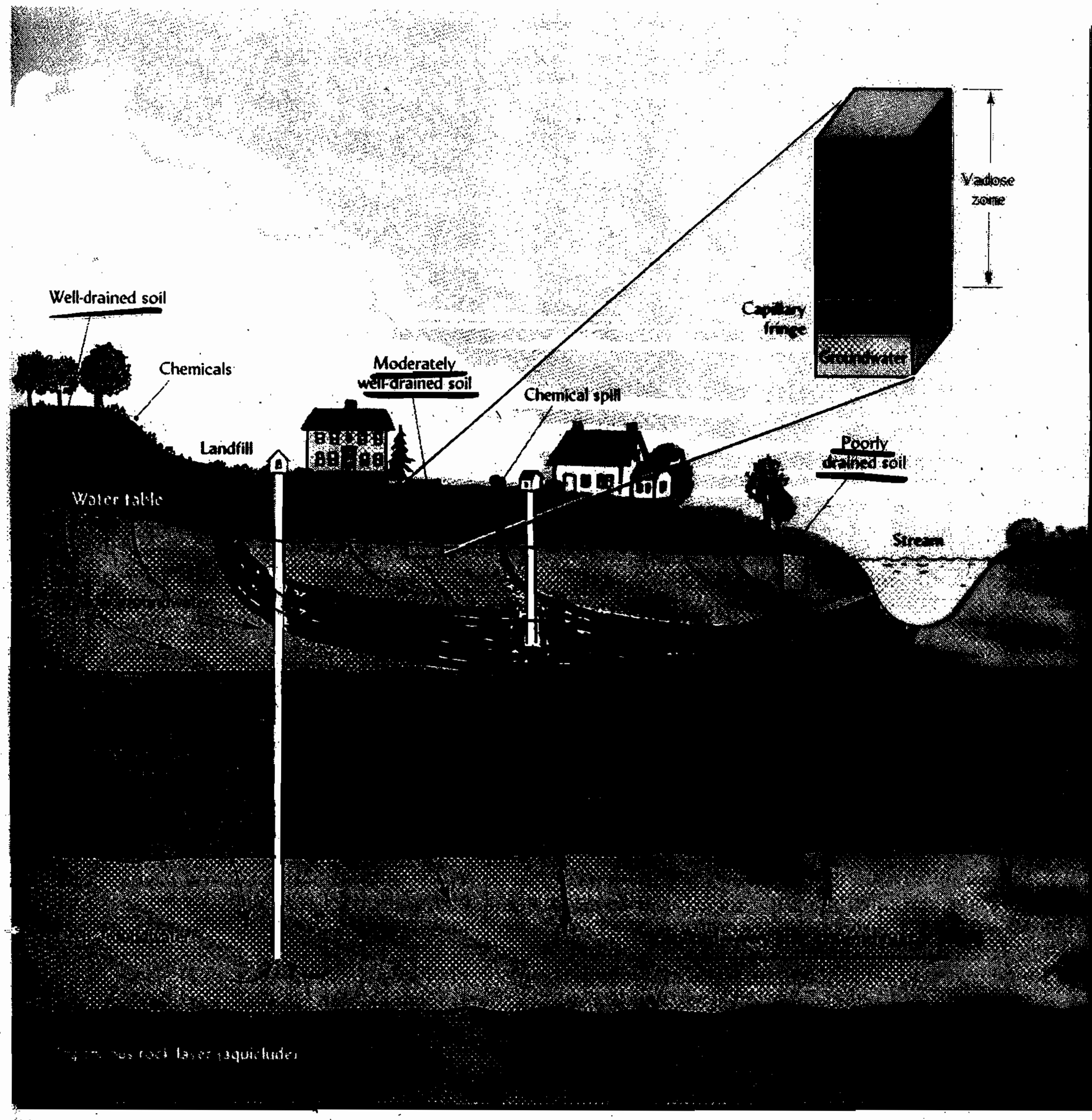


FIGURE 6.23 Relationship of the water table and groundwater to water movement into and out of the soil. Precipitation and irrigation water move down the soil profile under the influence of gravity (gravitational water), ultimately reaching the water table and underlying shallow groundwater. The unsaturated zone above the water table is known as the *vadose zone*. As water is removed from the soil by evapotranspiration, groundwater moves up from the water table by capillarity in what is termed the *capillary fringe*. Groundwater also moves horizontally down the slope toward a nearby stream, carrying with it chemicals that have leached through the soil, including essential plant nutrients (N, P, Ca, etc.) as well as pesticides and other pollutants from domestic, industrial, and agricultural wastes. Groundwaters are major sources of water for wells, the shallow ones removing water from the groundwater near the surface, while deep wells exploit deep and usually large groundwater reserves. Two plumes of pollution are shown, one originating from landfill leachate, the other from a chemical spill. The former appears to be contaminating the shallow well.

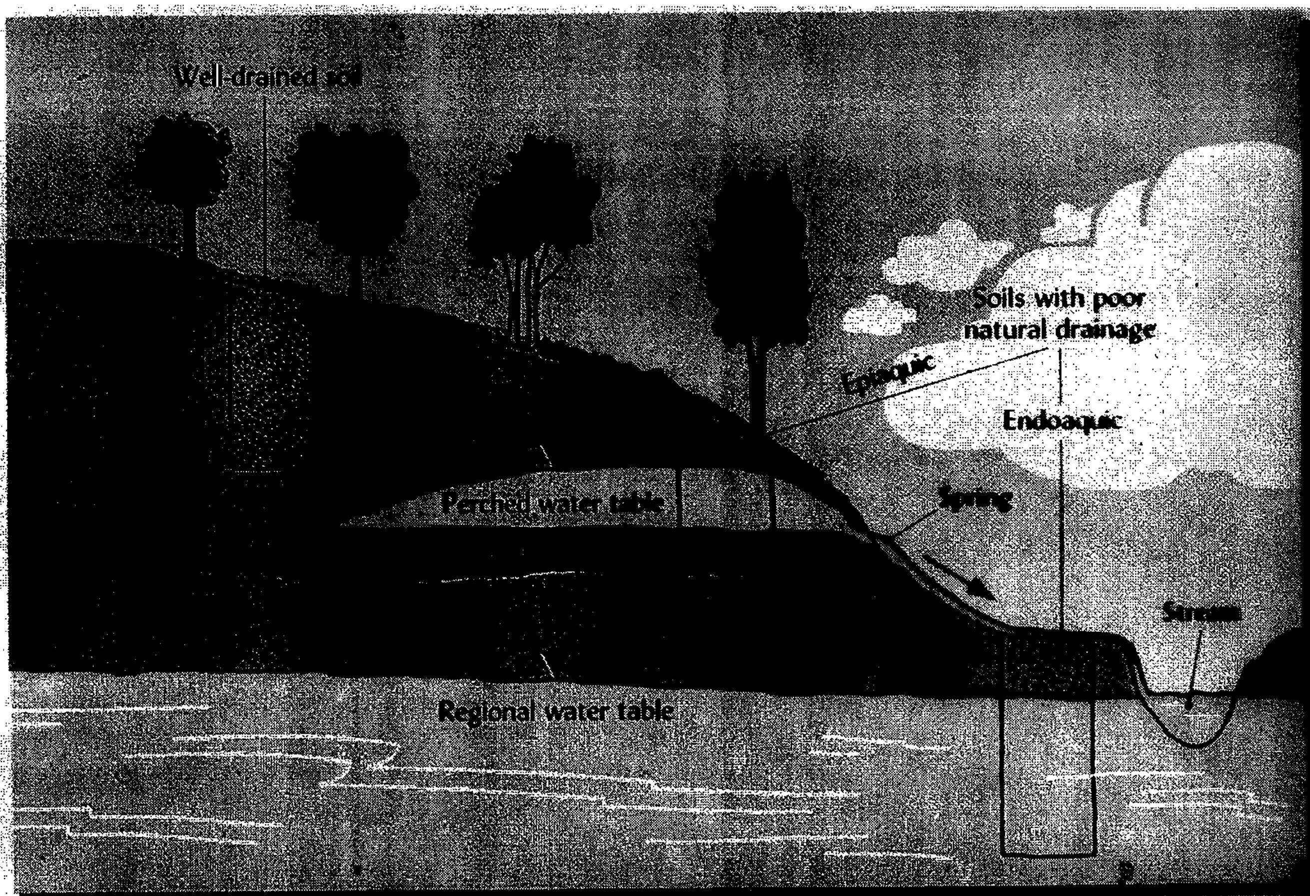
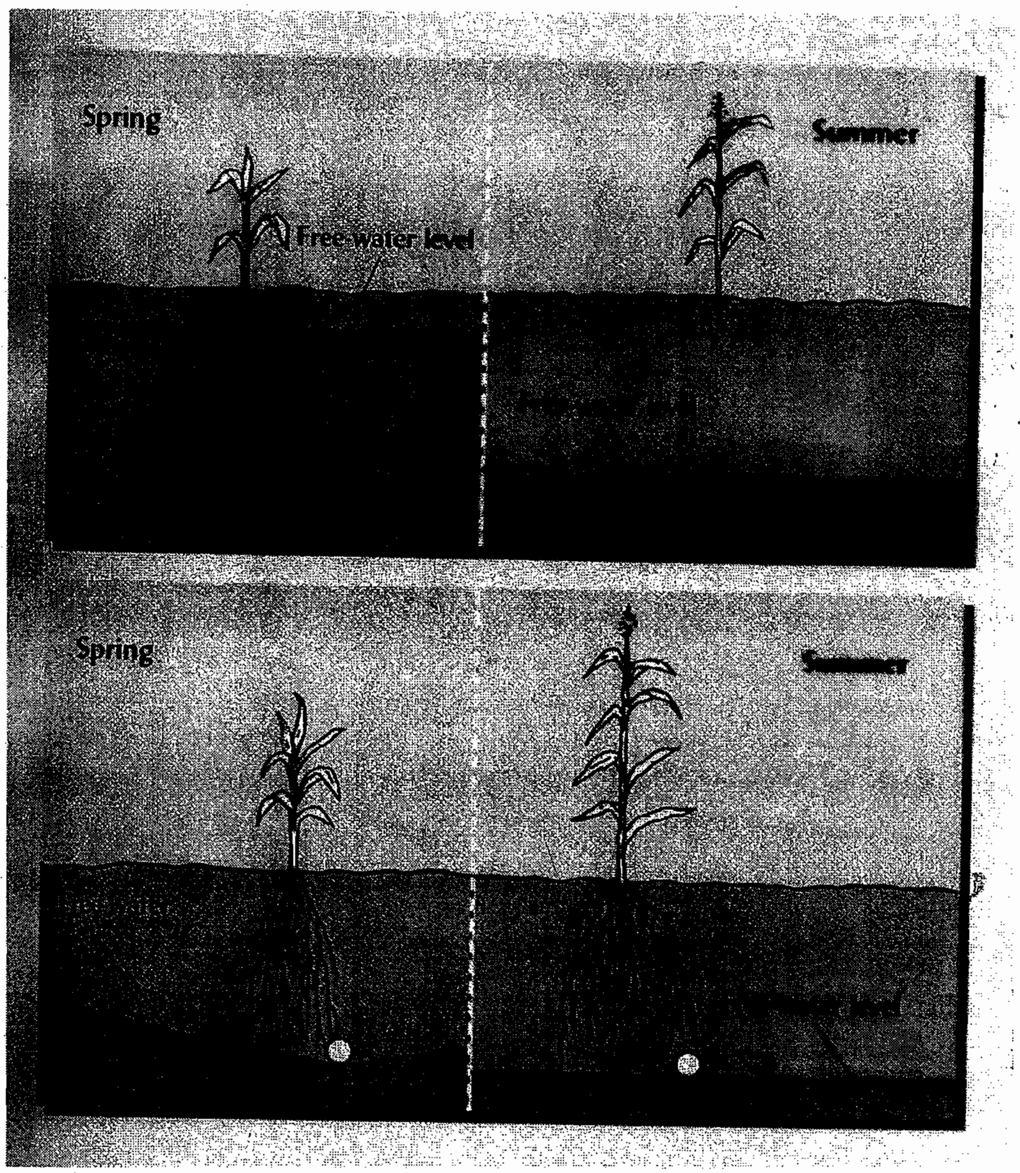
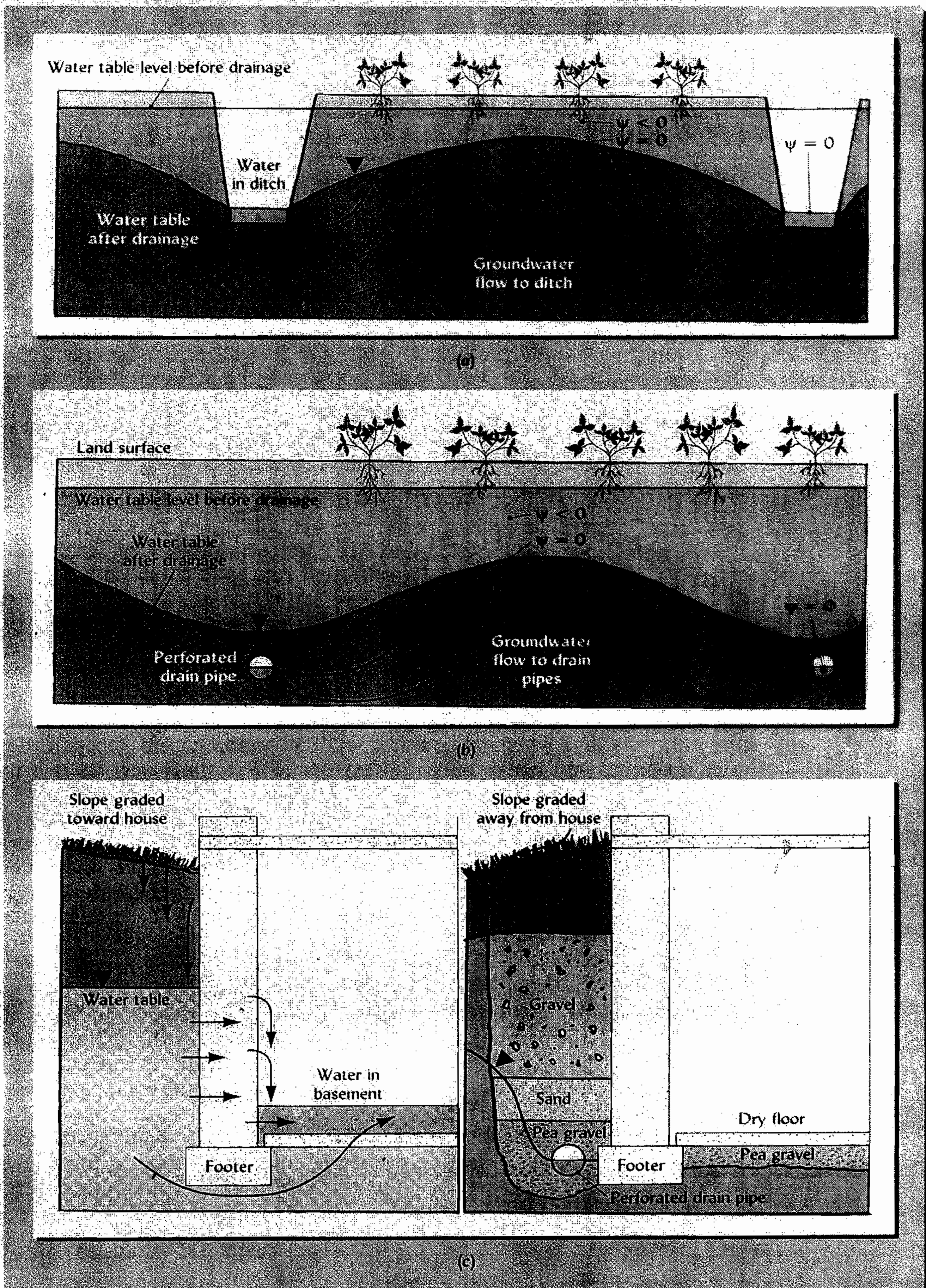


FIGURE 6.26 Cross-section of a landscape showing the regional and perched water tables in relation to three soils, one well-drained and two with poor internal drainage. By convention, a triangle (▼) is used to identify the level of the water table. The soil containing the perched water table is wet in the upper part, but unsaturated below the impermeable layer, and therefore is said to be *epiaquic* (Greek *epi*, upper), while the soil saturated by the regional water table is said to be *endoaquic* (Greek endo, under). Artificial drainage can help to lower both types of water tables.


Spring
Free-water level
Summer
Spring
Summer


Water table level before drainage
Water in ditch
ψ < 0
ψ = 0
ψ = 0
Water table after drainage
Groundwater flow to ditch
(a)
Land surface
Water table level before drainage
ψ < 0
ψ = 0
Water table after drainage
ψ = 0
Perforated drain pipe
Groundwater flow to drain pipes
(b)
Slope graded toward house
Water table
Water in basement
Footer
Slope graded away from house
Gravel
Sand
Pea gravel
Footer
Dry floor
Pea gravel
Perforated drain pipe
(c)

Artificial drainage systems- two general types:

1. Surface Drainage
2. Internal or Subsurface Drainage.

Benefits of Artificial Drainage

1. Increased bearing strength and improved soil workability, which allow more timely field operations and greater access to vehicular or foot traffic.

2. Reduced frost heaving of foundations, pavements, and crop plants.

3. Enhanced rooting depth, growth, and productivity of most upland plants due to improved oxygen supply and, in acid soils, lessened toxicity of manganese and iron.

4. Reduced levels of fungal disease infestation in seeds and on young plants.

5. More rapid soil warming in spring, resulting in earlier maturing crops.

6. Less production of methane and nitrogen gases that cause global environmental damages.

7. Removal of excess salts from irrigated soils, and prevention of salt accumulation by capillary rise in areas of salty groundwater.

Detrimental Effects of Artificial Drainage

1. Loss of wildlife habitat, especially waterfowl breeding and over-wintering sites.

2. Reduction in nutrient assimilation and other biochemical functions of wetlands.

3. Increased leaching of nitrates and other contaminants to groundwater.

4. Accelerated loss of soil organic matter, leading to subsidence of certain soils.

5. Increased frequency and severity of flooding due to loss of runoff water retention capacity.

6. Greater cost of damages when flooding occurs on alluvial lands developed after drainage.

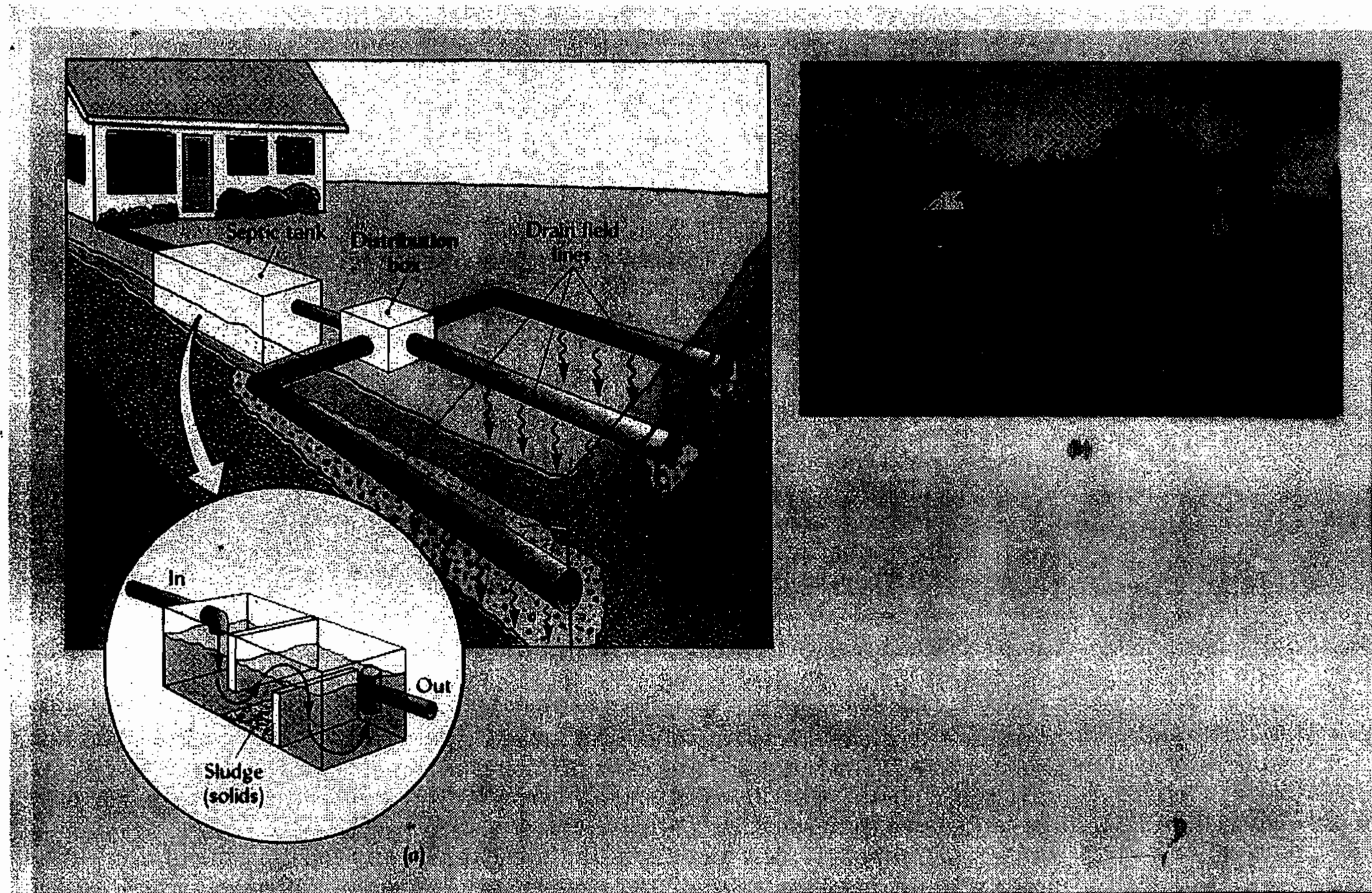


FIGURE 6.36 (*a*) A septic tank and drain field comprising a standard system for on-site wastewater treatment. Most of the solids suspended in the household wastewater settle out in the concrete septic tank. Effluent from the tank flows to the drain field, where it seeps out of the perforated pipes and into the soil. In the soil, the effluent is purified by microbial, chemical, and physical processes as it percolates toward the groundwater. (*b*) Photo shows the tell-tale dark strips of lawn where poorly functioning septic tank drain lines are stimulating the grass with wastewater and nitrogen. (Photo courtesy of R. Weil)

TABLE 6.7 Soil Properties Influencing Suitability for a Septic Tank Drain Field

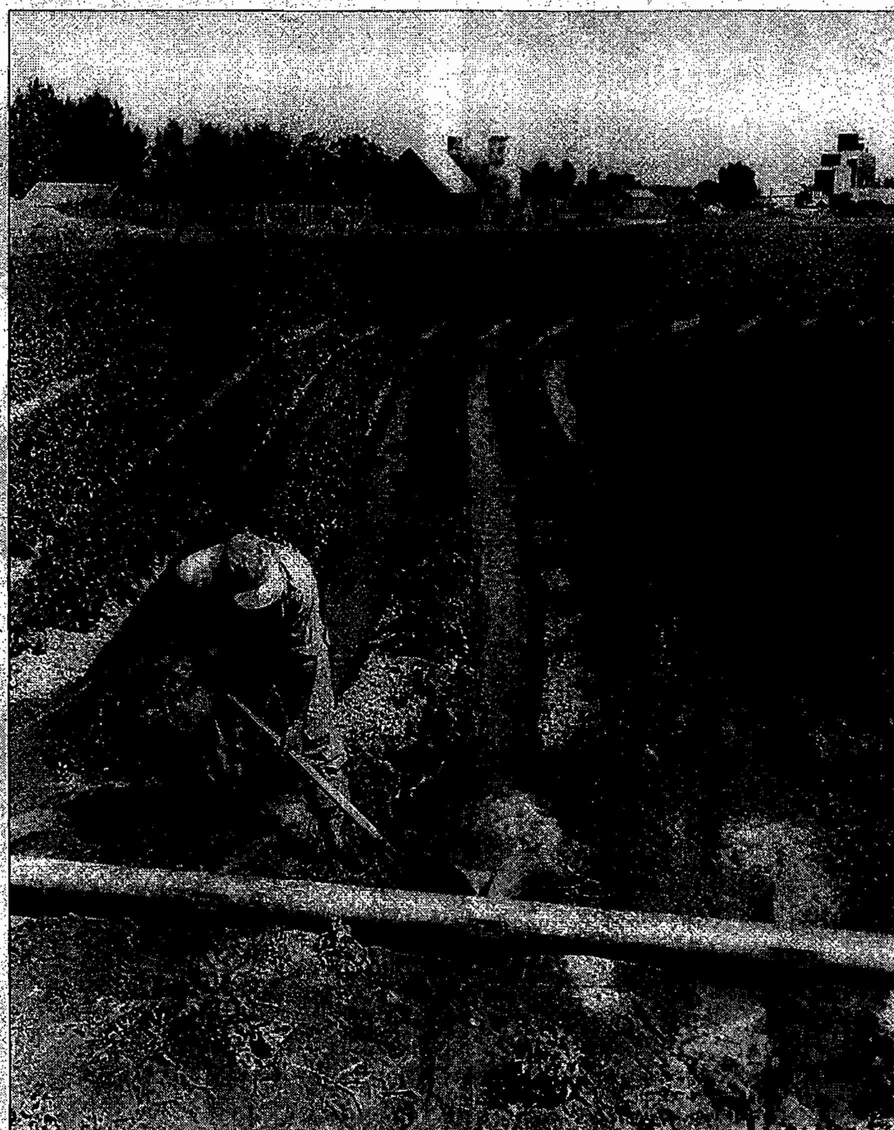
Note that most of these soil properties pertain to the movement of water through the soil profile.

	Limitations		
Soil property[a]	*Slight*	*Moderate*	*Severe*
Flooding	—	—	Floods frequent to occasional
Depth to bedrock or impermeable pan, cm	>183	102–183	<102
Ponding of water	No	No	Yes
Depth to seasonal high water table, cm	>183	122–183	<122
Permeability (perc test) at 60 to 152 cm soil depth, mm/h	50–150	15–50	<15 or >150[b]
Slope of land, %	<8	8–15	>15
Stones >7.6 cm, % of dry soil by weight	<25	25–50	>50

[a] Assumes soil does not contain permafrost and has not subsided more than 60 cm.

[b] Soil permeability (as determined by a perc test) greater than 150 mm/h is considered too fast to allow for sufficient filtering and treatment of wastes.

Adapted from Soil Survey Staff (1993), Table 620-17.



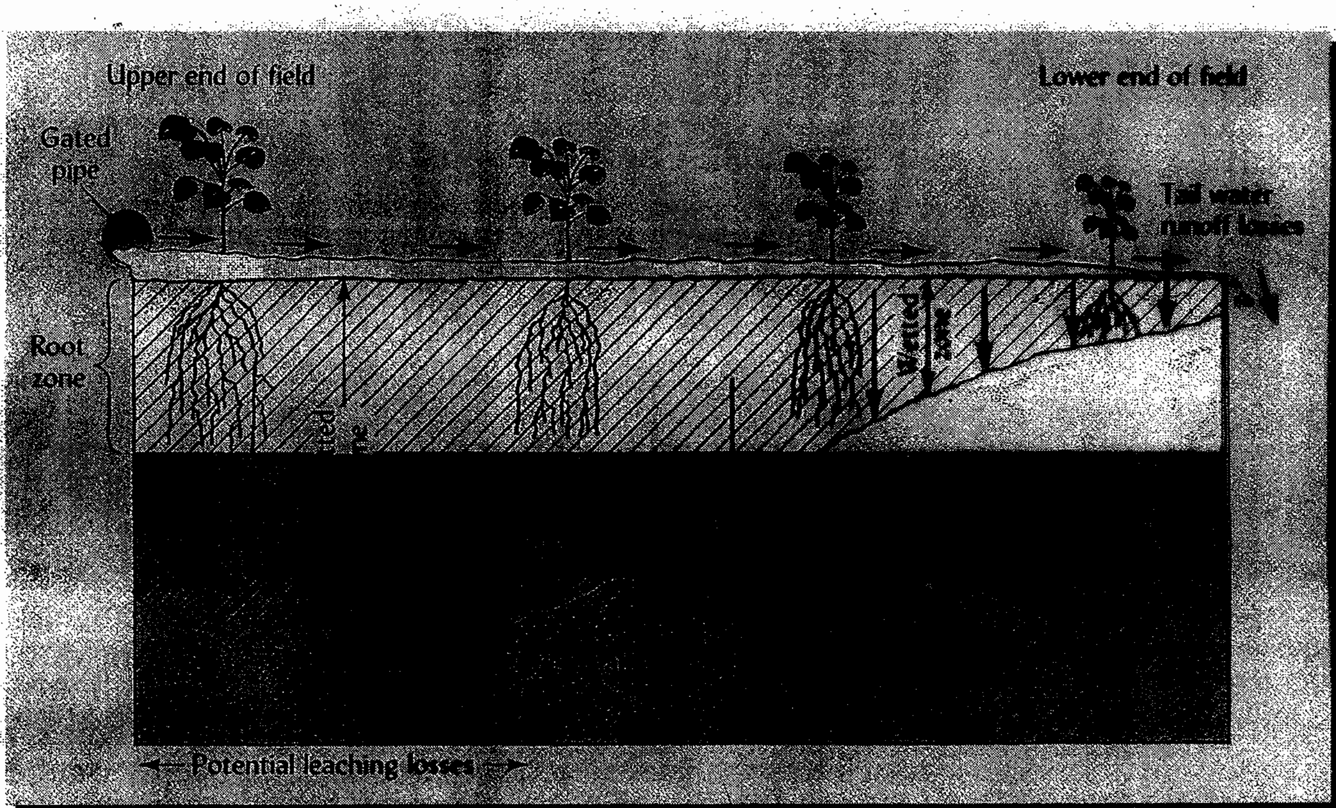


FIGURE 6.42 Penetration of water into a coarse-textured soil under surface irrigation. The high infiltration rate causes most of the water to soak in near the gated pipe at the upper end of the field. The uneven penetration of water results in the potential for leaching losses of water and dissolved chemicals at the upper end of the field, while plants at the lower end may receive insufficient water to moisten the entire potential root zone. On a less-permeable soil, or on a field with a steep slope, the tail water runoff losses would likely be greater at the lower end and leaching potential less at the upper end.

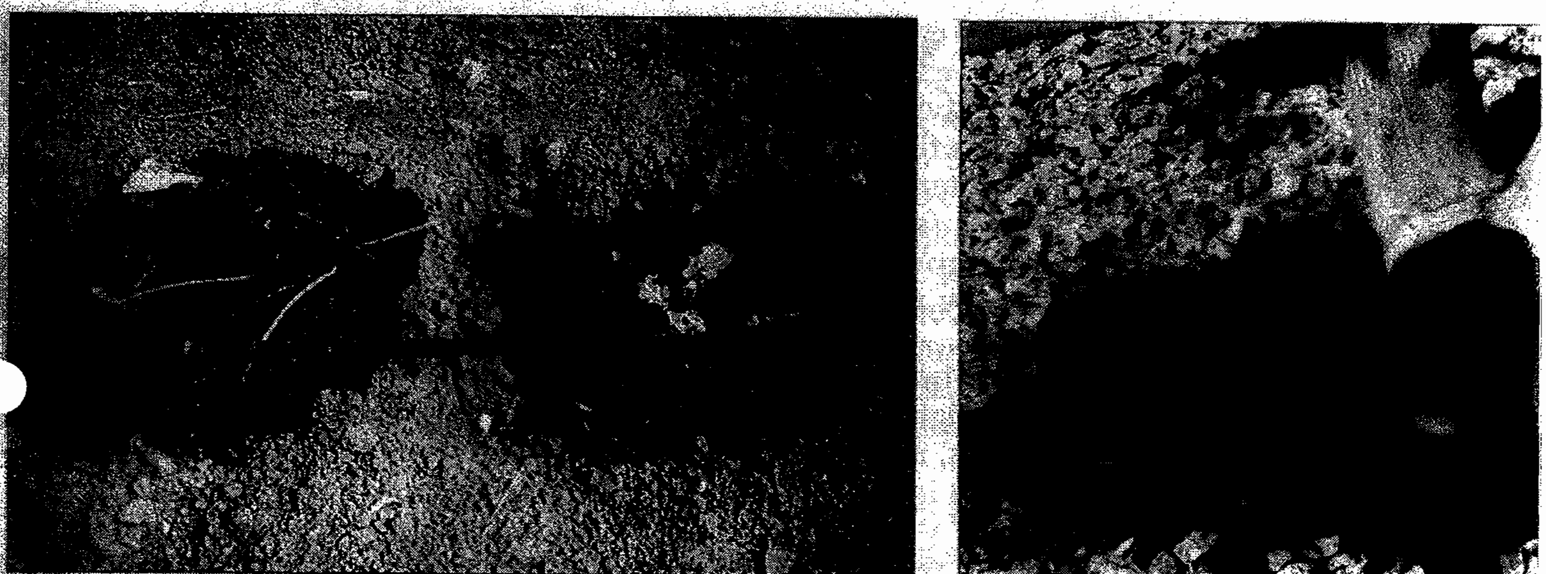


FIGURE 6.45 Two examples of microirrigation. (Left) *Drip* or *trickle* irrigation with a single emitter for each seedling in Africa. (Right) A *microsprayer* or *spitter* irrigating an individual tree in a home garden in Arizona. In both cases, irrigat small portion of the soil in the immediate root zone. Small quantities of water applied at high frequency (such as on assures that the root zone is kept almost continuously at an optimal moisture content. (Left photo courtesy of R. Weil