Chapter 15
Soil Resources

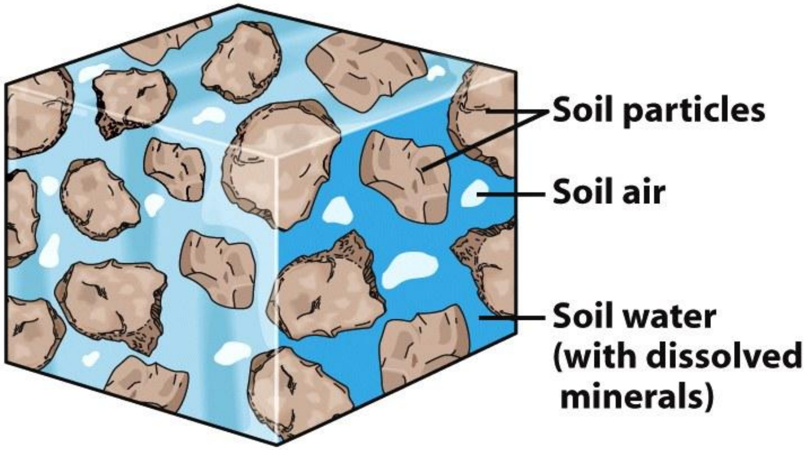
I. Soil

- A. Uppermost layer of Earth's crust that supports plants, animals and microbes
- B. Soil Forming Factors
  - 1. Parent Material – rock that is slowly broken down or fragmented into smaller and smaller particles by biological, chemical, and physical weathering processes in nature
  - 2. Time – to form 2.5 cm (1 inch) of topsoil may require between 200 and 1000 years
  - 3. Climate – alternate freezing and thawing of water produces cracks
  - 4. Organisms – release carbon dioxide which mixes with water to form carbonic acid – this forms tiny cracks which are intensified by the freezing and thawing of water
  - 5. Topography – steep slopes have little to no soil because the soil is transported down the slope by gravity

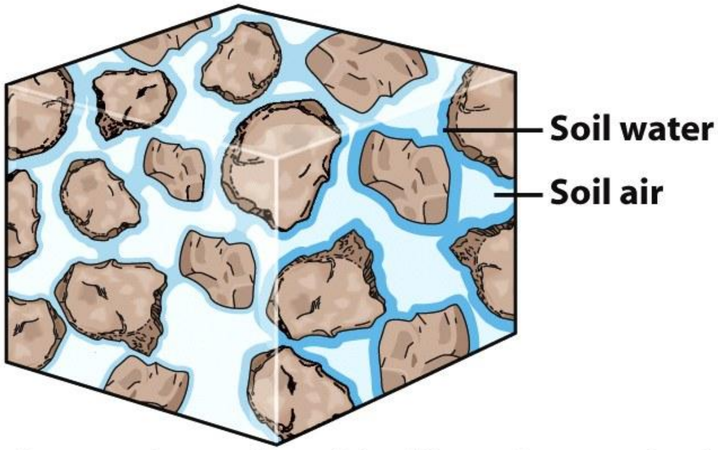
II. Soil Composition

- A. Mineral Particles (45%)
  - Weathered rock
- B. Organic Material (5%)
  - Litter, animal dung, dead remains of plants and animals
  - Increases the soils water holding capacity by acting like a sponge
  - Humus – black or dark-brown organic material that remains after much decomposition has occurred – binds to nutrient mineral-ions and holds water
- C. Water (25%)
- D. Air (25%)

- E. Pore space
  - 50% of soil is pore space
  - Soil air – pore space that is filled with air -good for aeration
  - Soil water – pore space that is filled with water - provides water to roots



(a) In a wet soil, most of the pore space is filled with water.

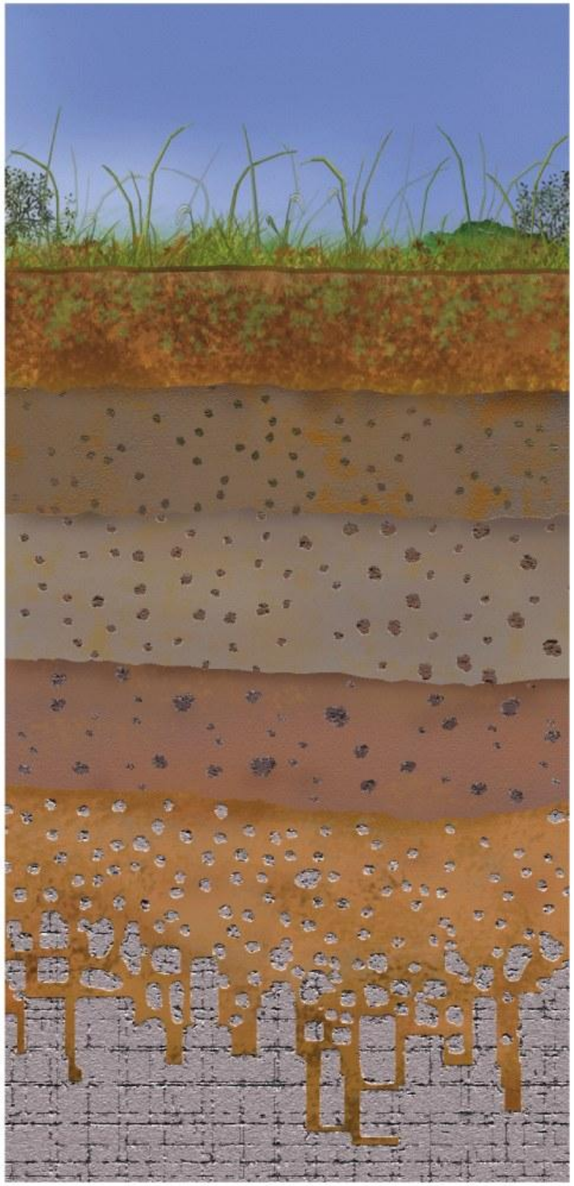


(b) In a dry soil, a thin film of water is tightly bound to soil particles, and soil air occupies most of the pore space.

III. Soil Horizons

- A. O-horizon – uppermost layer of soil – rich in organic material – plant litter accumulates and gradually decays – in desert soils this layer is often completely absent, but in organically rich soils it may be the dominant layer
- B. A-horizon – also known as the topsoil – dark and rich in accumulated organic matter and humus – somewhat nutrient poor because of leaching
- C. E-horizon – this layer may form between the A and B layers – heavily leached
- D. B-horizon – lighter colored subsoil – zone of accumulation in which nutrient minerals that leached out accumulate – often rich in iron compounds, aluminum compounds and clay
- E. C-horizon – weathered pieces of rock and borders the unweathered solid parent material – below most of the roots and often saturated with ground water

Soil Horizons



O-horizon
(accumulation of plant litter)

A-horizon
(accumulation of organic matter and humus)

E-horizon
(heavily leached)

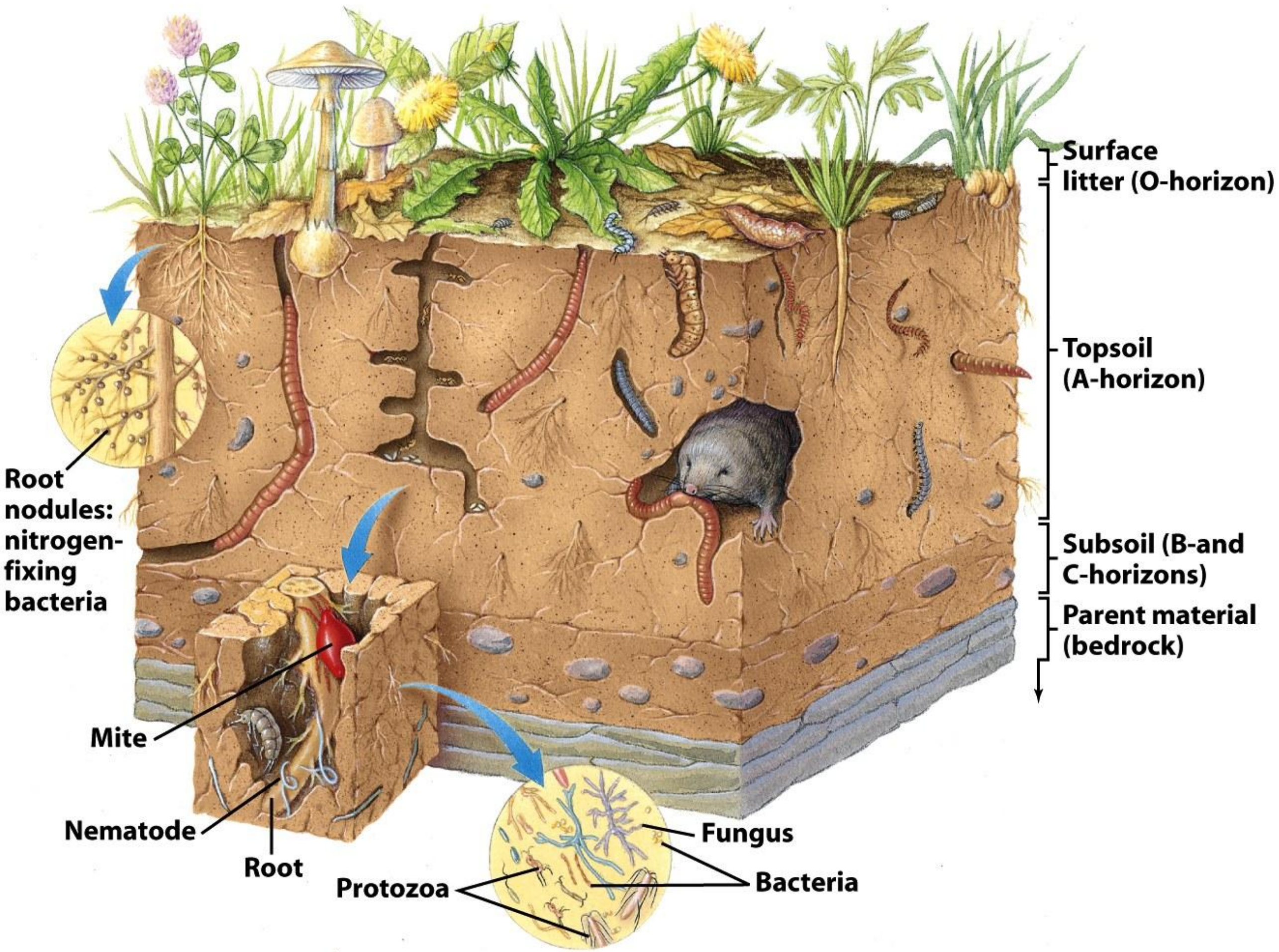
B-horizon
(accumulation of clay and nutrient minerals)

C-horizon
(weathered pieces of rock)

Solid parent material
(bedrock)

IV. Soil Organisms

- A. There are millions of microorganisms in 1 tsp of fertile agricultural soil



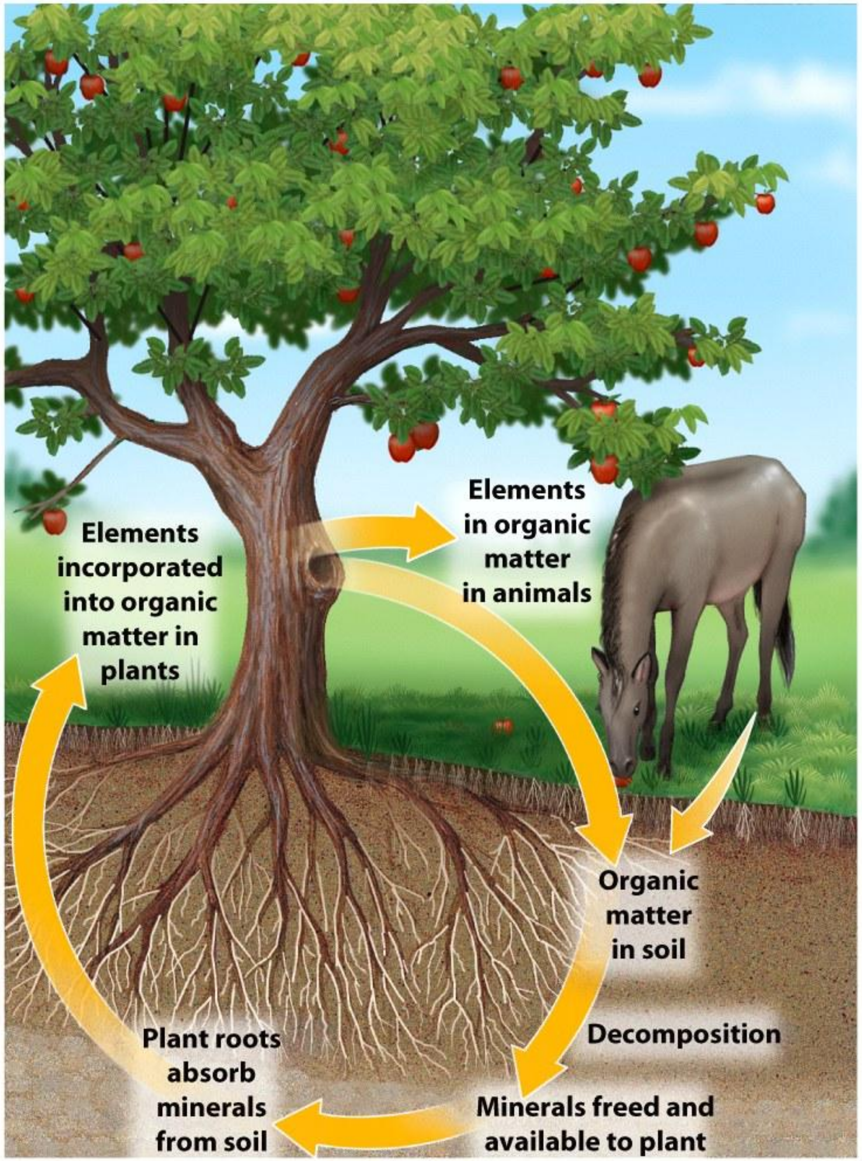
- B. Soil organisms provide ecosystem services - important environmental benefits that ecosystems provide
  - 1. Decaying and cycling organic material
  - 2. Breaking down toxic materials
  - 3. Cleansing water
  - 4. Soil aeration
  - 5. Preventing soil erosion
  - 6. Affecting the composition of the atmosphere

- C. Earthworms
  - 1. ingest soil – castings, bits of soil that have passed through the gut of the earthworm, are deposited on the soil surface – nutrients from deeper layers of the soil are brought to upper layers
  - 2. earthworm tunnels serve to aerate the soil
  - 3. worms’ waste products and corpses add organic material to the soil

- D. Symbiotic relationship
  - 1. Fungi and the roots of vascular plants – mycorrhizae – help plants absorb adequate amounts of essential nutrients from the soil
  - 2. mycelium – threadlike body of fungus extends into the soil well beyond the roots to absorb nutrients to give to the plant
  - 3. plants goes through photosynthesis and makes food which is given to the fungus

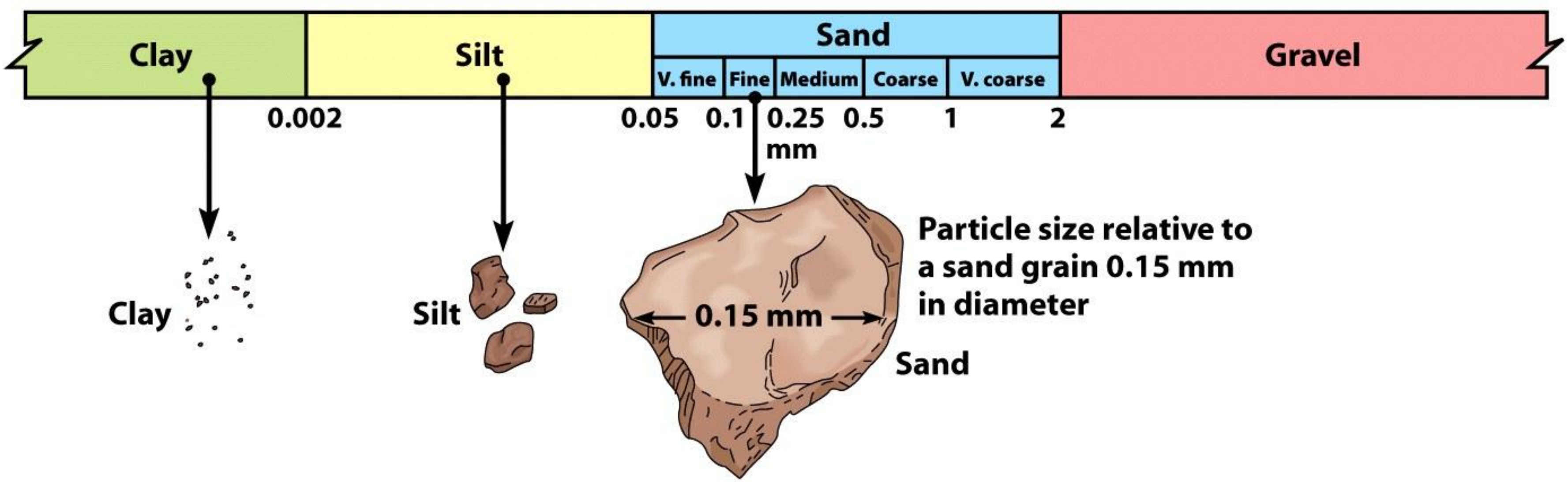
IV. Nutrient Cycling

- Nutrients are cycled between plants, organisms and soil

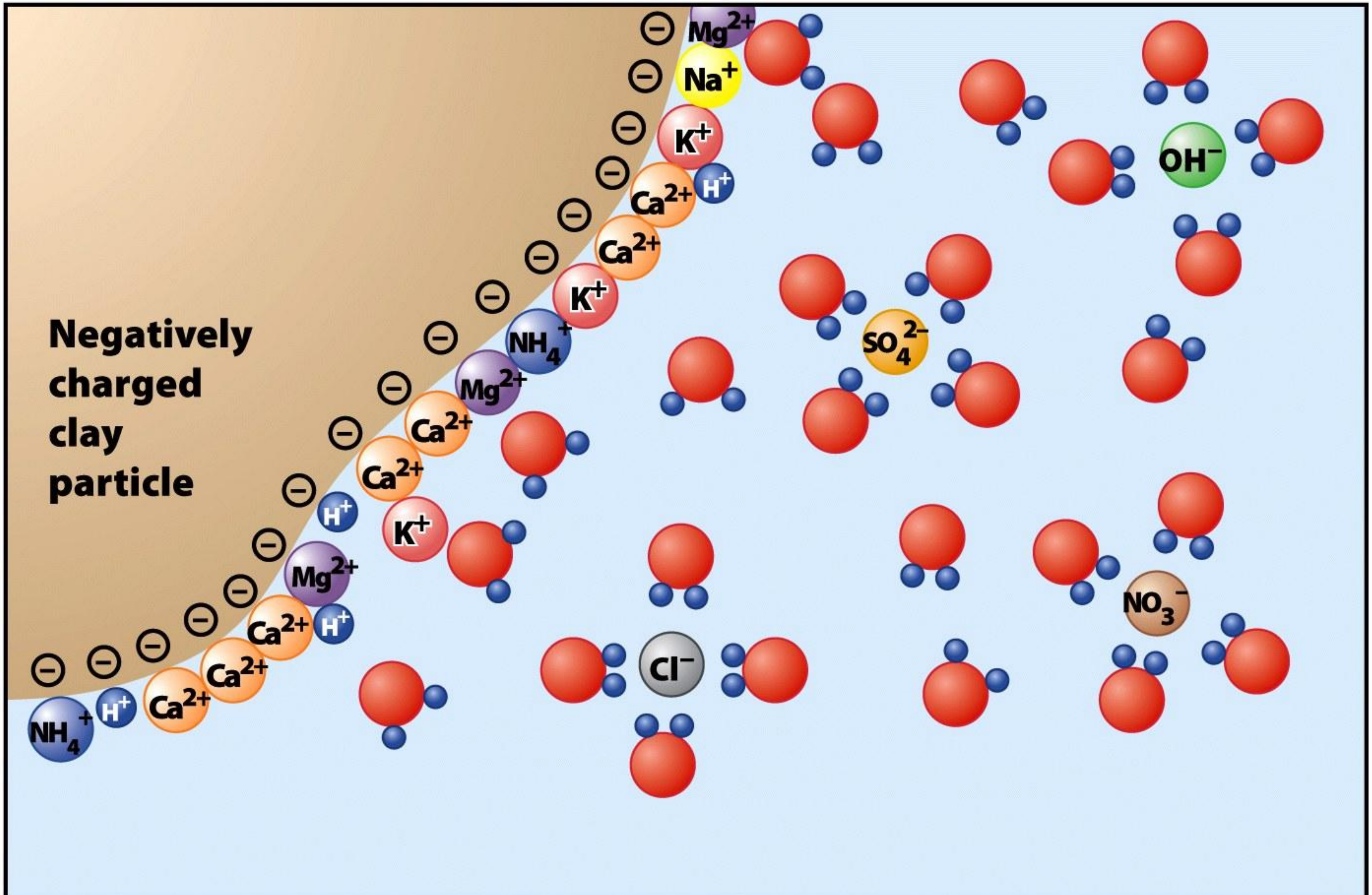


V. Soil Properties

- A. Soil Texture
  - Relative proportion of sand, silt and clay
  - Sand: 2mm–0.05 mm
  - Silt: 0.05mm–0.002 mm
  - Clay: >0.002 mm



- B. Soil texture affects soil properties
- C. Coarse textured soil (sandy)
  - Excellent drainage
- D. Fine textured soil (high in clay)
  - Poor drainage
  - Low oxygen levels in soil
  - Due to negatively charged surface, able to hold onto important plant nutrients (K^+, Ca^{2+}, NO^{2-})


Negatively
charged
clay
particle
Mg^{2+}
Na^+
K^+
H^+
Ca^{2+}
NH_4^+
OH^-
SO_4^{2-}
Cl^-
NO_3^-

Soil Properties

Table 15.1 Soil Properties Affected by Soil Texture

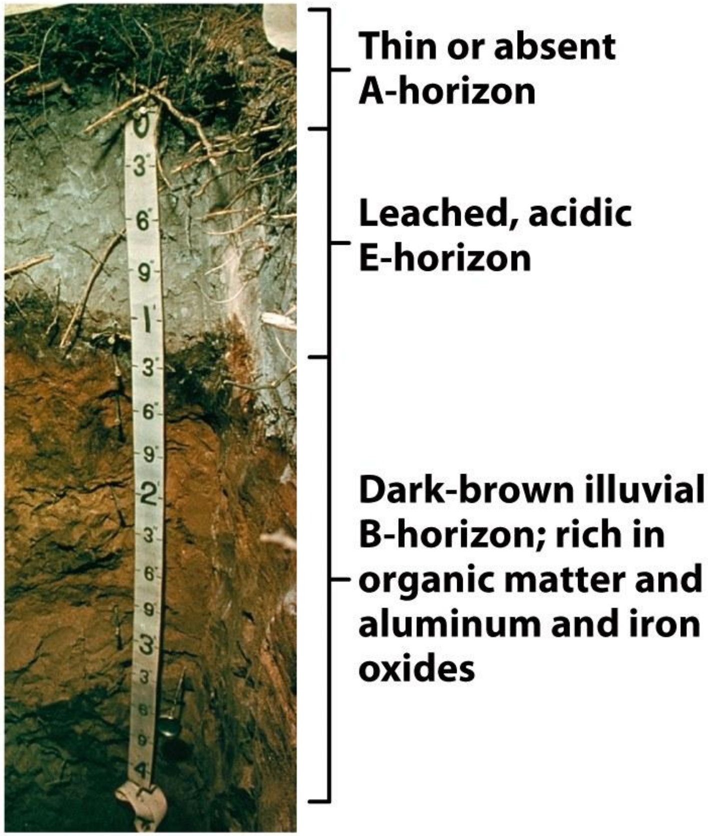
	Soil Texture Type		
Soil Property	***Sandy Soil***	***Loam***	***Clay Soil***
Aeration	Excellent	Good	Poor
Drainage	Excellent	Good	Poor
Nutrient mineral–holding capacity	Low	Medium	High
Water-holding capacity	Low	Medium	High
Workability (tillage)	Easy	Moderate	Difficult

- E. Soil Acidity
  - 1. Measured using pH scale
  - 2. pH of most soils range from 4–8
  - 3. Affects solubility of certain plant nutrients
    - Low pH – aluminum and manganese become more soluble and the plants can absorb them in toxic concentrations
    - High pH – mineral salts essential for plant growth such as calcium phosphate become less soluble and less available to plants
  - 4. Optimum soil pH is 6–7, because nutrients are most available to plants at this pH
  - 5. Soil pH greatly affects the leaching
    - Acidic soil – reduced ability to bind to positively charged ions – K+ is leached more easily

VI. Major Soil Groups

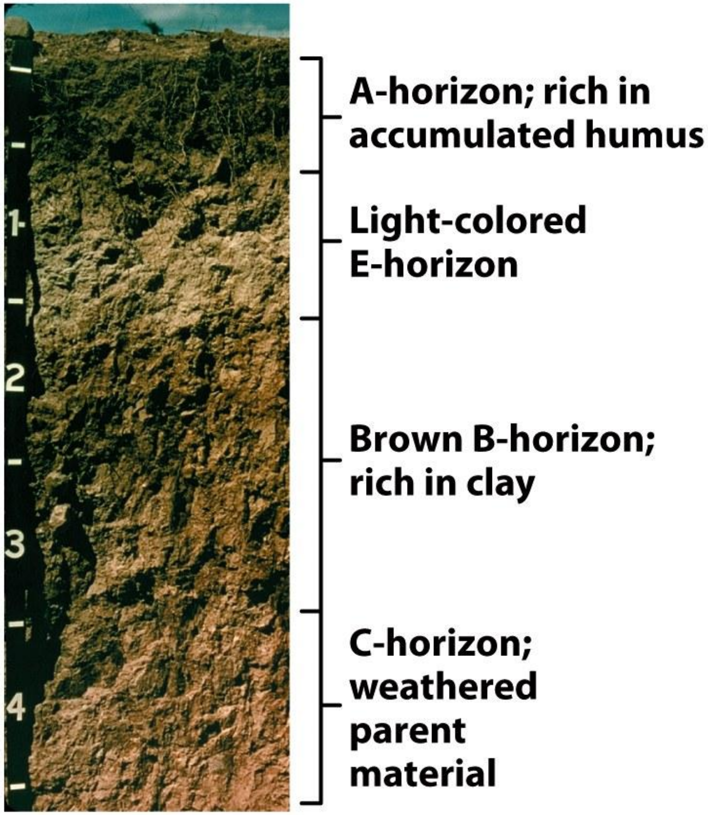
- A. Variations in soil forming factors cause variation in soils around globe
- B. Soil Taxonomy
  - Separates soils into 12 orders
  - Subdivided into more than 19,000 soil series that vary by locality
- C. Five common soil orders
  - Spodosols, alfisols, mollisols, aridosols, oxisols

- D. Spodosols – colder climates, ample precipitation, and good drainage
  - Form under coniferous forests
  - O-horizon composed of decaying needles (acidic)
  - E-horizon is ash -gray and leached under A-horizon
  - B horizon is dark brown and illuvial
  - Not good farmland - too acidic and too few nutrients due to leaching



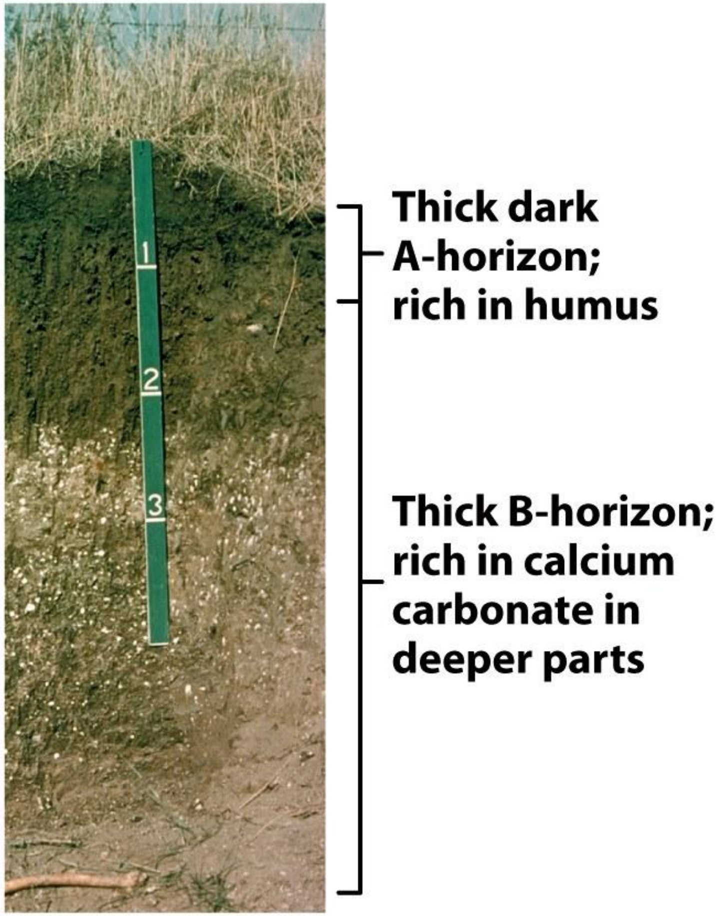
Spodosol in cold (subarctic) climate. Characteristic of evergreen forests. Photographed in the Great Lakes region.

- E. Alfisols – temperate deciduous forests
  - Brown to gray-brown A-horizon
  - Precipitation high enough to leach most organics and nutrients out of the A and E horizon into the B horizon
  - Soil fertility maintained by leaf litter
  - When soil is cleared for farmland, fertilizers (nitrogen, potassium, and phosphorus) must be used to maintain fertility



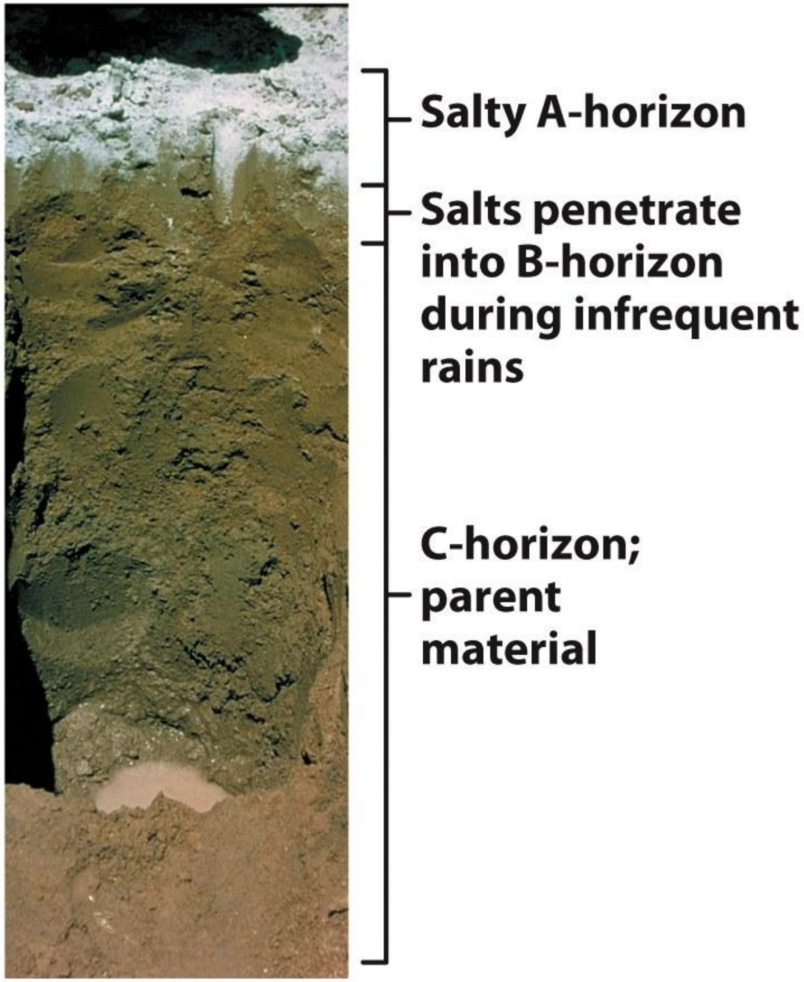
Alfisol in humid climate with hot summers and cold winters. Characteristic of temperate, deciduous forest. Photographed in southern Michigan.

- F. Mollisols
  - Found in temperate, semi-arid grassland
  - Very fertile soil
  - Thick, dark brown/ black A-horizon – rich in humus
  - Soluble nutrients stay in A-horizon due to low leaching (not as much precipitation)
  - Most of the world's grain crops are grown on mollisols



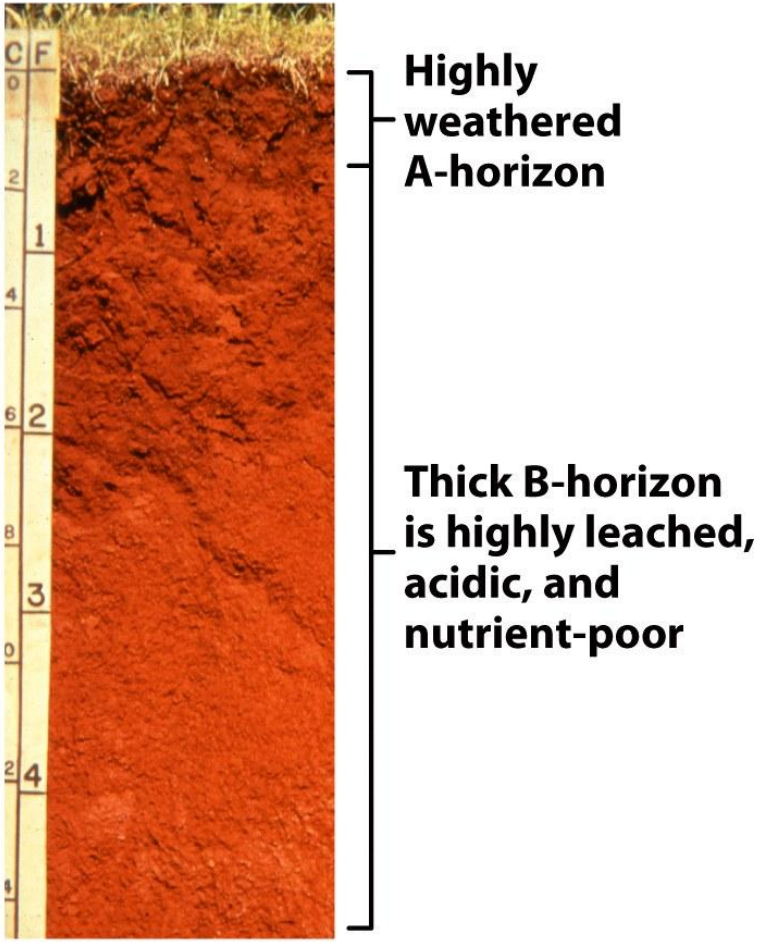
Mollisol in semiarid climate with hot summers and cold winters. Characteristic of temperate grassland. Photographed in North Dakota.

- G. Aridosols
  - Found in arid regions of all continents
  - Low precipitation preclude leaching and growth of lush vegetation – very little organic material
  - Development of salic (salty) A - horizon possible
  - Don't usually have distinct layers of leaching and illuviation



Aridosol in arid (dry) climate. Characteristic of desert. Photographed in Nevada.

- H. Oxisols
  - Found in tropical and subtropical areas with high precipitation
  - Very little organic material accumulation due to fast decay rate
  - B-horizon is highly leached and nutrient poor
  - Most nutrient minerals are locked up in the vegetation rather than in the soil



Oxisol in wet, warm climate. Characteristic of tropical rain forest. Photographed in Hawaii.

VII. Soil Problems

- A. Soil Erosion
  - Caused primarily by water and wind
- B. Why a problem?
  - Causes a loss in soil fertility as organic material and nutrients are eroded
  - More fertilizers must be used to replace nutrients lost to erosion
- C. Humans accelerate soil erosion by poor soil management practices
  - 1. construction of roads and buildings
  - 2. unsound logging practices
  - 3. poor agriculatural practices

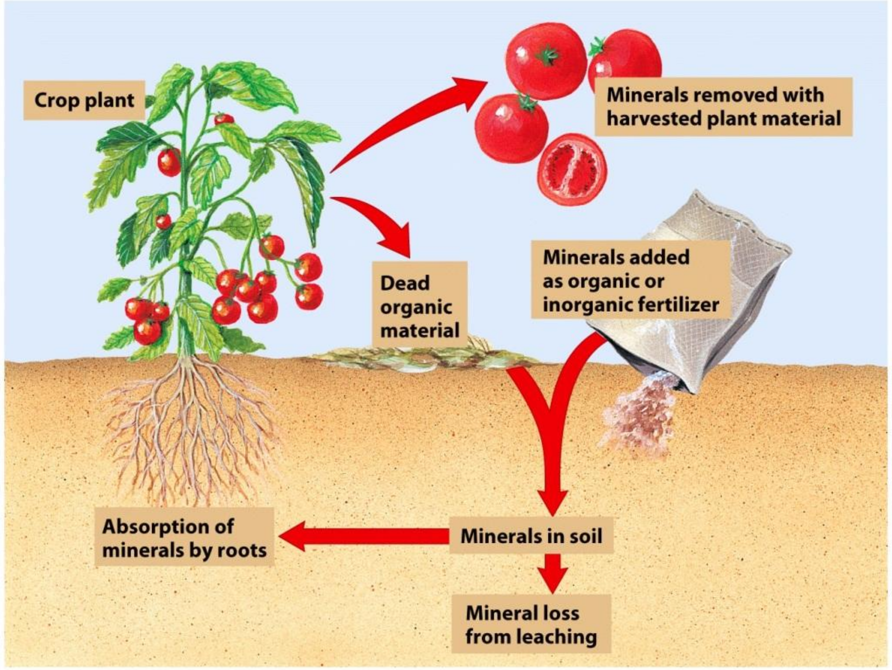
Soil Erosion by Water and Wind

- D. impact of soil erosion on other natural resources
  - 1. sediment gets into streams, rivers, and lakes which affects water quality and fish habitats
  - 2. if sediment contains pesticides and fertilizers, they further pollute the water
  - 3. when forests are removed within the watershed of a hydroelectric power facility, accelerated soil erosion causes the reservoir behind the dam to fill with sediment much faster than usual which results in a reduction of electricity production at that facility

- E. Soil Erosion in the United States and the World
  - 1. Natural Resources Conservation Service (NRCS) – formally known as the Soil Conservation Service – every 5 years, they measure the rate of soil erosion at thousands of sites across the US – also uses satellite data and models – findings:
    - a. NRCS has shown that erosion is still a serious threat to cultivated soils particularly in southern Iowa, northern Missouri, western and southern Texas and eastern Tennessee
    - b. NRCS has shown that the total soil erosion has decreased by about 38%
    - c. NRCS has shown that water erosion is particularly severe in the midwestern grain belt along the Mississippi and Missouri rivers as well as in the Central Valley of California and the Pacific Northwest
    - NRCS estimates that about 25% of US agricultural lands are losing topsoil faster than natural soil forming processes regenerate it
  - 2. Worldwide – results in the annual loss of as much as 75 billion metric tons (83 billion tons) of topsoil around the world - greatest in Asia, Africa, India, and Central and South America

- F. Case in Point: American Dust Bowl
  - 1. Great Plains has low precipitation and is subject to drought
    - 1930-1937 severe drought (65% less water than normal)
    - No natural vegetation roots to hold soil in place (removed prairie grasses to plant wheat – prairie grasses could have withstood the drought)
    - Replaced by annual crops (wheat – could not withstand the drought)
    - Winds blew soil as far east as NYC and DC.
    - Farmers went bankrupt (occurred during the Great Depression)
    - US Soil Conservation Service planted fence rows of shrubs and trees and replanted prairie grasses – Ogallala aquifer provides irrigation – could happen again if not managed properly

- G. Nutrient Mineral Depletion
  - when plants die, decomposers return their nutrients back to the soil – when crops are harvested, this cycle is disturbed and soil loses fertility
  - Caused by many factors including unsound farming methods, extensive soil erosion, and desertification – as well as growing populations
  - Especially severe in tropical rain forests



- H. Soil Salinization
  - Gradual accumulation of salt in the soil, usually due to improper irrigation techniques

- Often in arid and semi-arid areas
- Salt concentrations get to levels toxic to plants

- I. Desertification
  - degradation of once-fertile rangeland, agricultural land, or tropical dry forest into nonproductive desert
  - Asia and Africa have the largest areas with extensive soil damage – rapid population growth compounds the problem
  - To reclaim the land you would need to restrict its use for many years

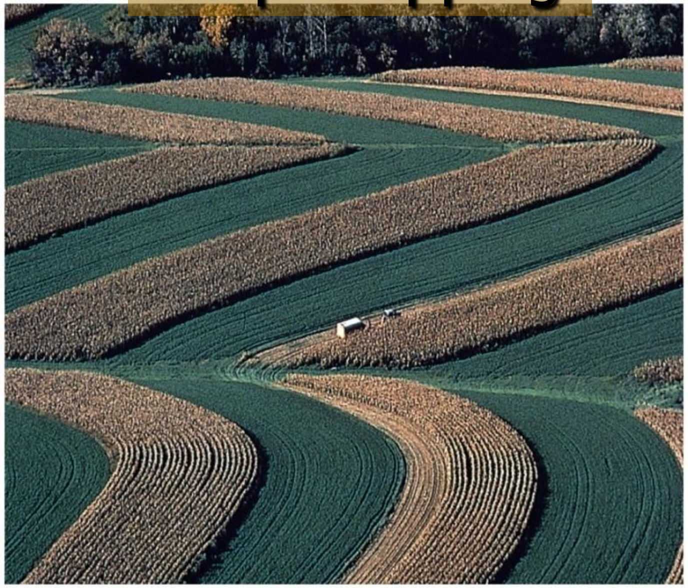
VIII. Soil Conservation

- A. Conservation Tillage
  - Residues from previous year's crops are left in place to prevent soil erosion – one type is called no-tillage – increases organic matter in the soil and reduces soil erosion

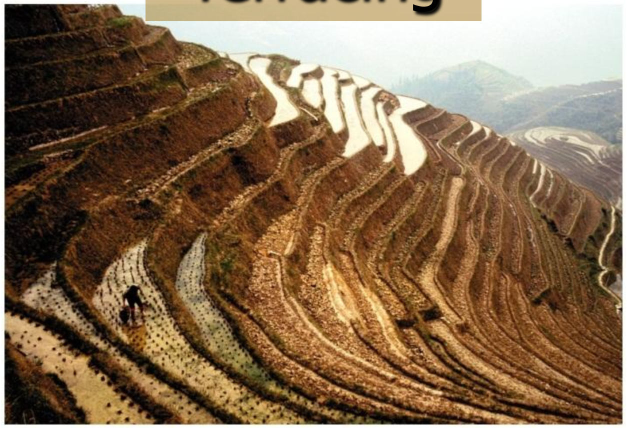
- B. Crop Rotation
  - Planting a series of different crops in the same field over a period of years – lessens insect damage and disease – soybeans and alfalfa are often rotated in because they increase soil fertility (legumes with nitrogen fixing bacteria)

- C. Contour Plowing
  - Plowing around hill instead of up-down
- D. Strip Cropping
  - Alternating strips of different crops along natural contours
- E. Terracing
  - Creating terraces on steep slopes to prevent erosion

Strip Cropping



Terracing

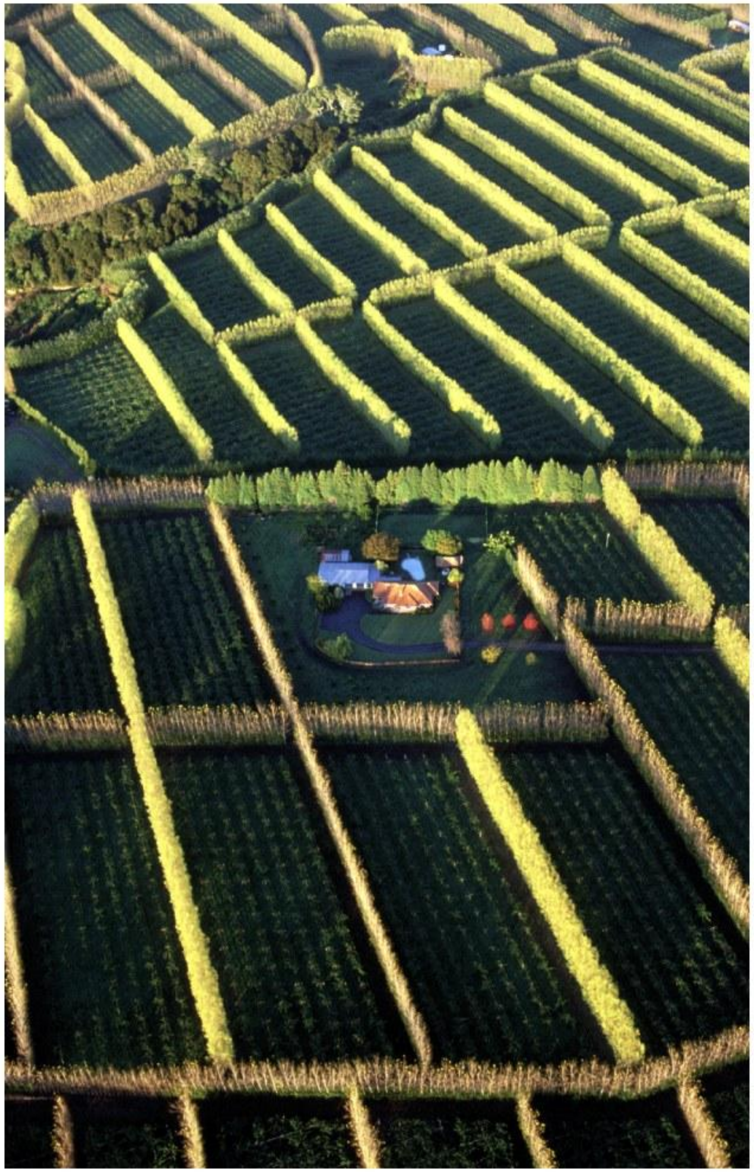


IX. Preserving Soil Fertility

- A. Organic fertilizers
  - Animal manure, crop residue, bone meal and compost
  - Nutrient available to plants only as material decomposes – slow acting and long lasting
- B. Inorganic fertilizers
  - Manufactured from chemical compounds
  - Soluble
    - Fast acting, short lasting
    - Mobile - easily leach and pollute groundwater
  - Should be avoided for two reasons:
    - 1. often leach into ground water or surface runoff and pollute the water
    - 2. do not improve the water-holding capacity of the soil as organic fertilizers do

C. Soil Reclamation

- 1. Two steps
  - a. Stabilize land to prevent further erosion – bare ground is seeded with plants that eventually grow to cover the soil and hold it in place
  - b. Restoring soil to former fertility – as dead portions of the plant are converted to humus, fertility begins to be restored
- 2. Best way to do this is shelterbelts – agroforestry - trees and crops are planted together
  - a. Row of trees planted to reduce wind erosion of soil



D. Soil Conservation Policies in US

- 1. Soil Conservation Act 1935
  - Authorized formation of Soil Conservation Service, now called Natural Resource Conservation Service (NRCS)
  - Assess soil damage and develop policies to improve soil
- 2. Food Security Act (Farm Bill) 1985
  - Farmers with highly erodible soil had to change their farming practices
  - Instituted Conservation Reserve Program
    - Pays farmers to stop farming highly erodible land