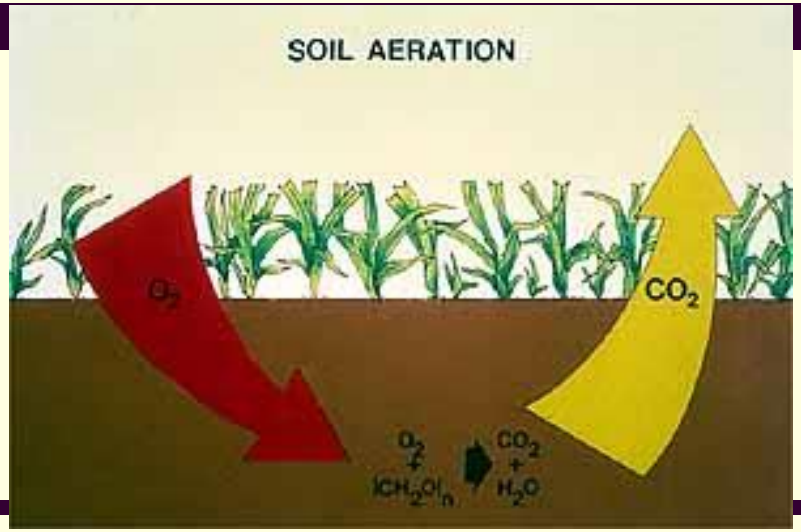
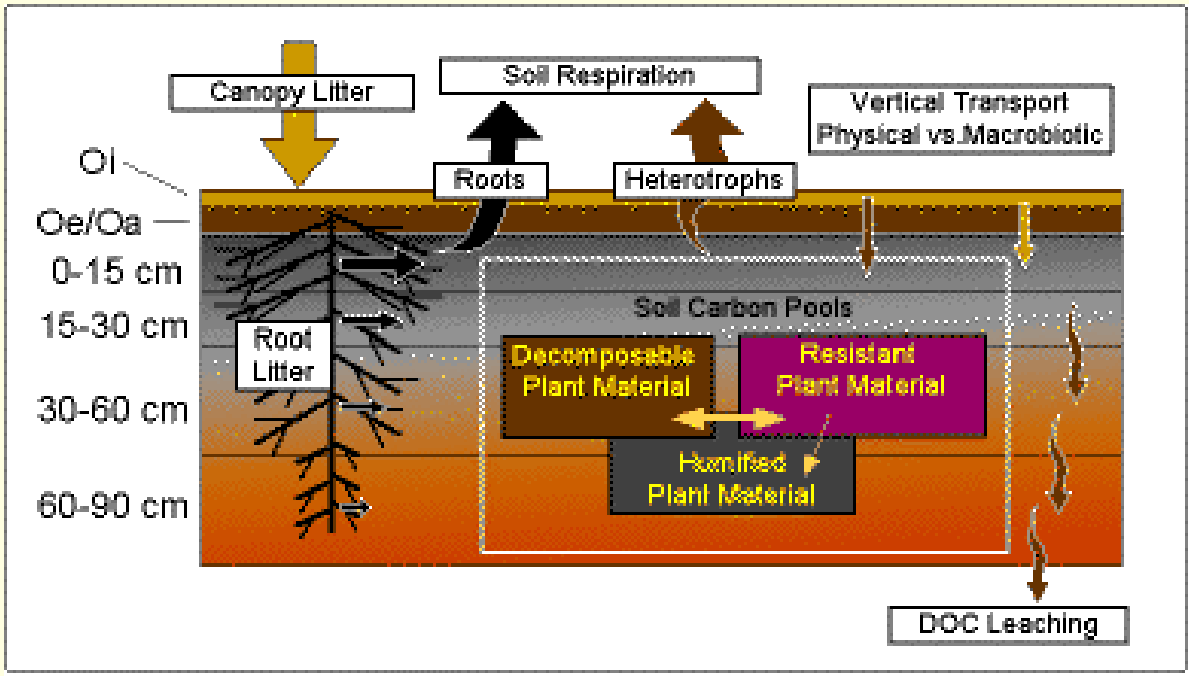
SOIL AERATION AND TEMPERATURE



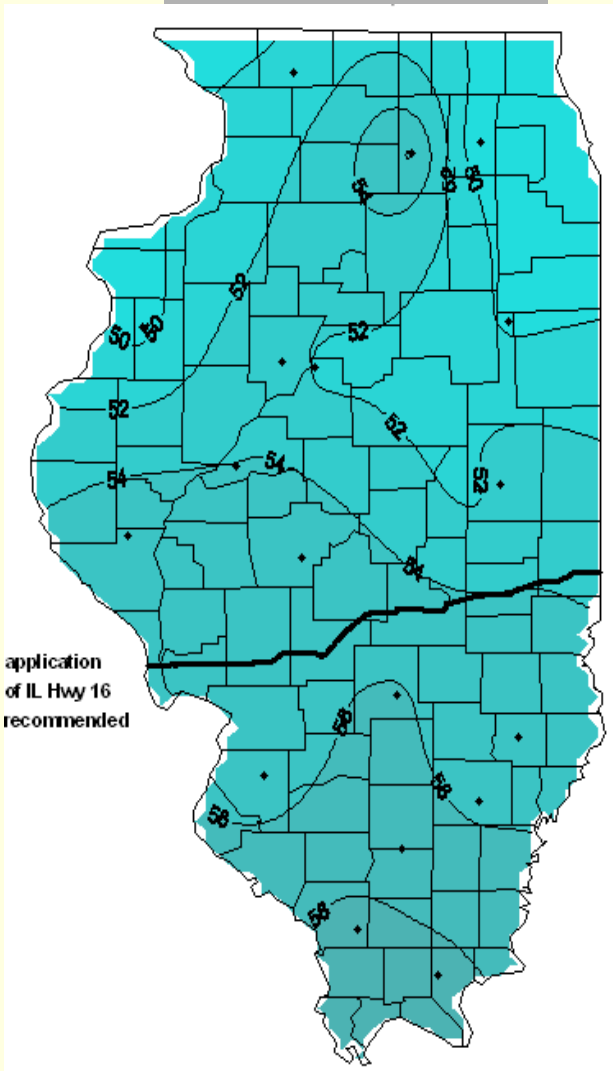
INTRODUCTION

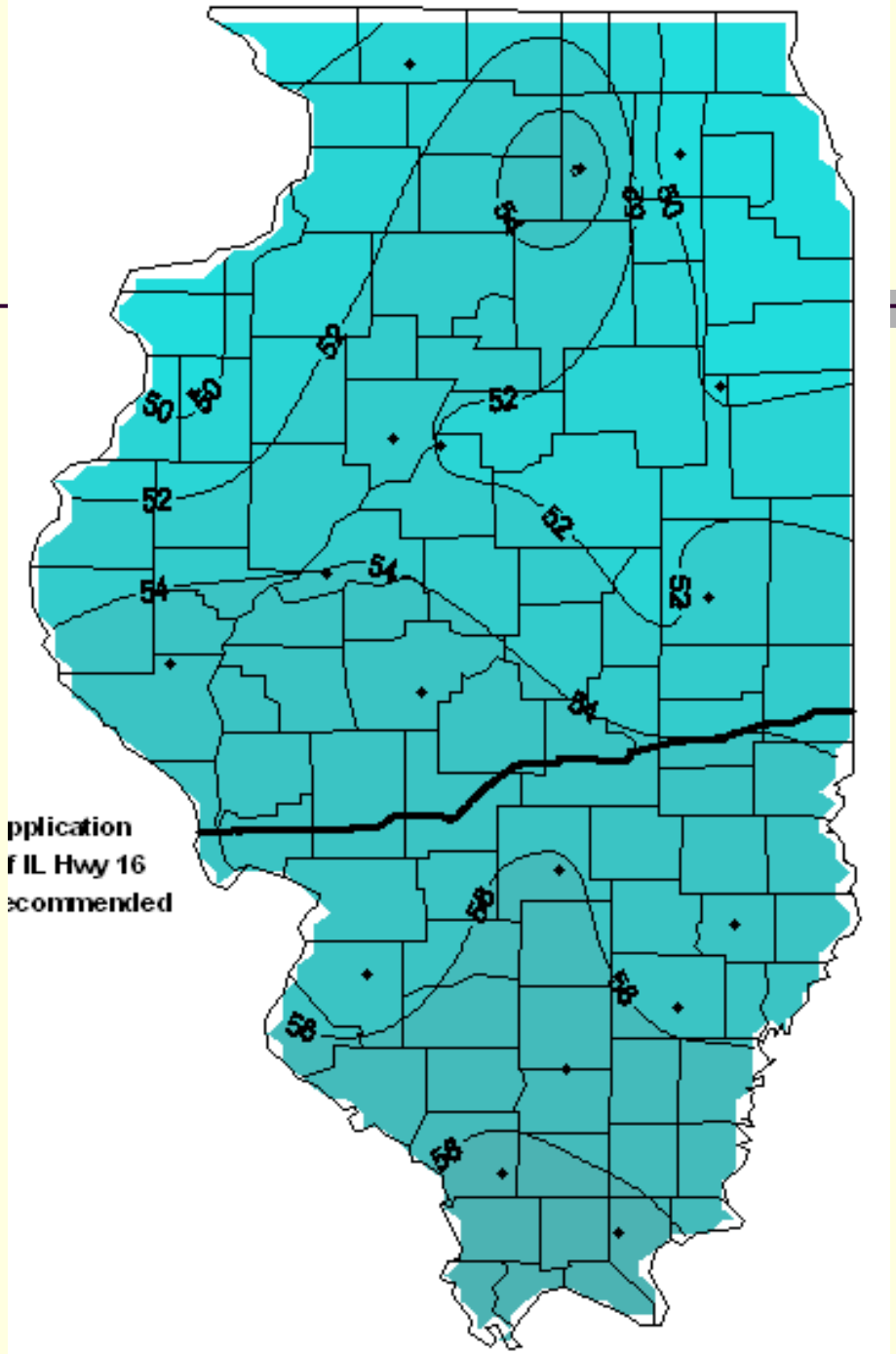
- **Aeration** is directly impacted by soil:
  - Texture and structure
  - Porosity, water movement and retention
  - Microbes



INTRODUCTION

- **Soil temperature** affects:
  - Plant growth
  - Growth of microbes
  - Soil drying
  - Soil aeration
  - Physical and chemical properties

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THE PROCESS OF SOIL AERATION

- **Aeration** involves:
  - Ventilation of the soil
  - Gas movement into and out of the soil
  - Determines the rate of gas exchange

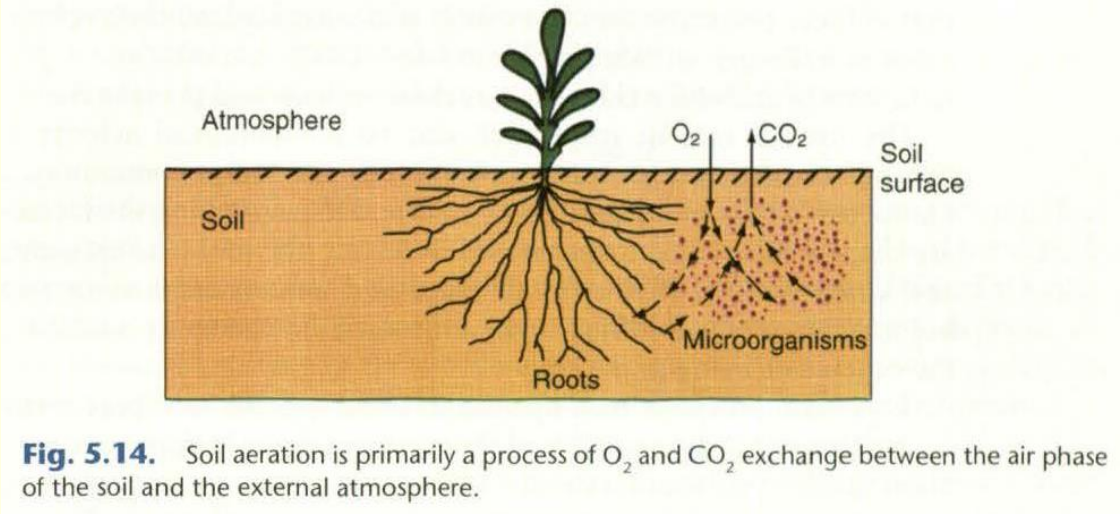
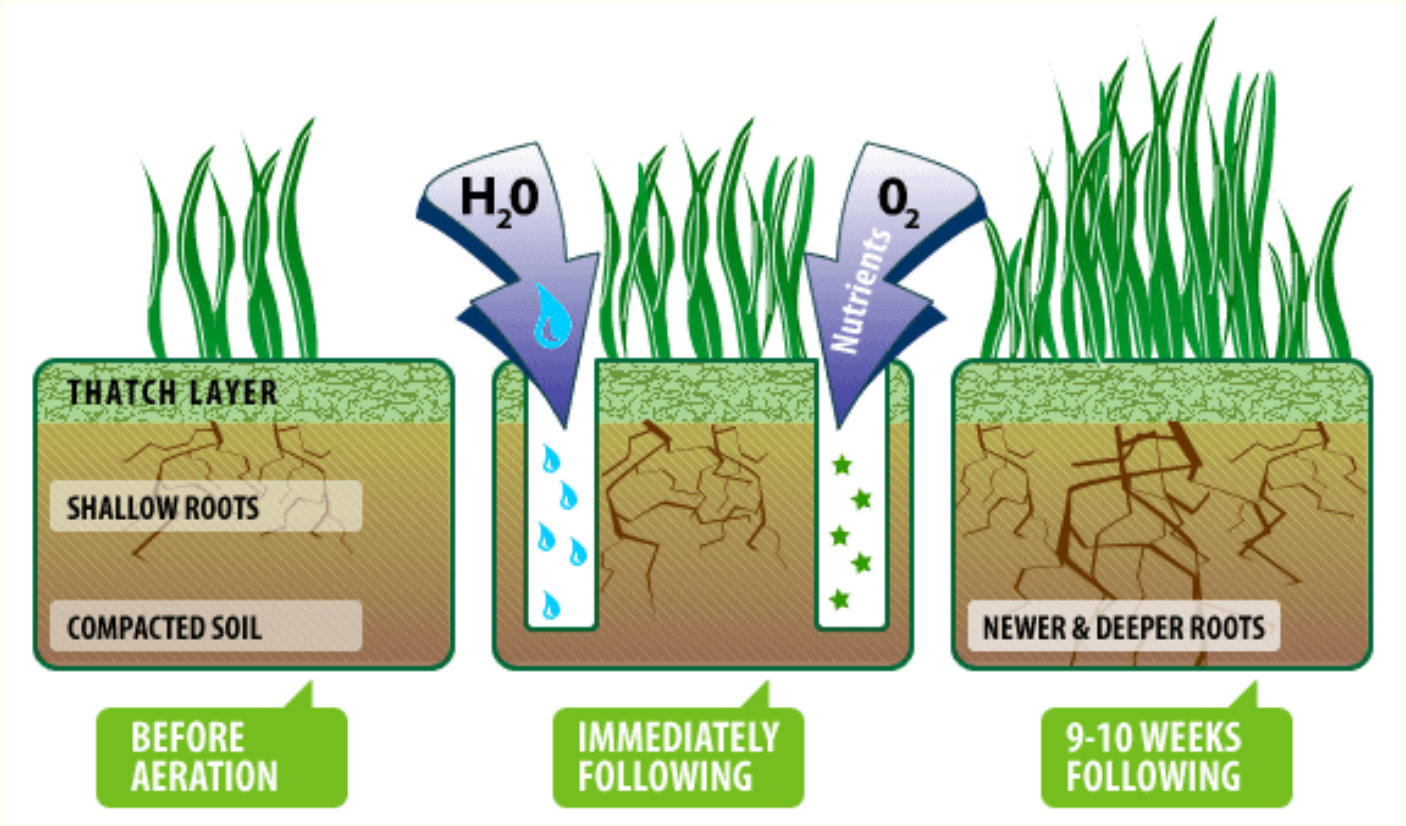


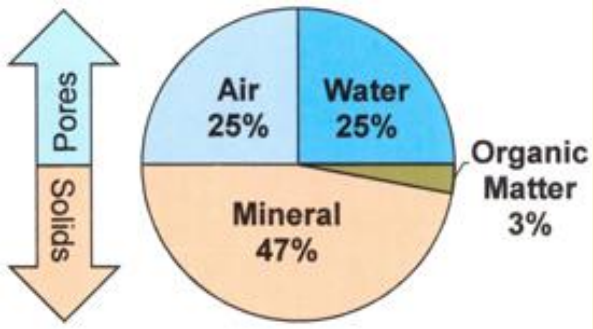
Fig. 5.14. Soil aeration is primarily a process of O_2 and CO_2 exchange between the air phase of the soil and the external atmosphere.

SOIL AERATION



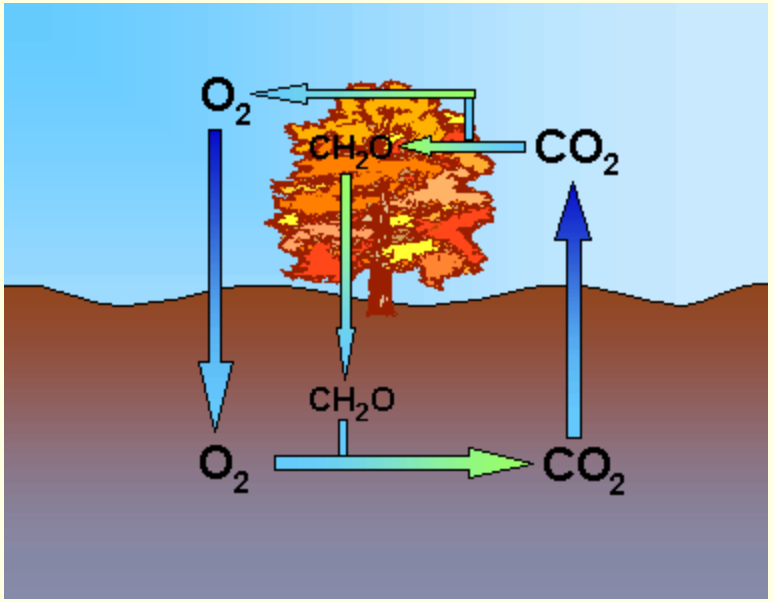
THE PROCESS OF SOIL AERATION

- **Aeration** involves:
  - Proportion of pore spaces filled with air
  - Composition of soil air
  - Oxidation/reduction potential



THE PROCESS OF SOIL AERATION

- **Aeration** requires:
  - Supply oxygen
  - Removal of CO_2
  - **Balance between O_2 and CO_2 in well-aerated soils**

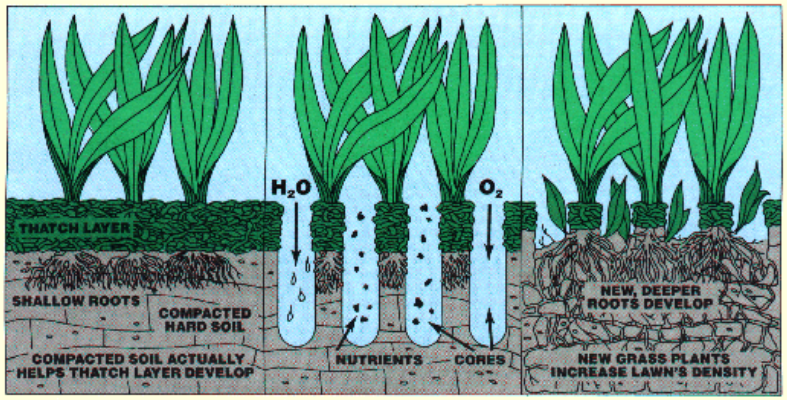


AERATION REQUIREMENTS FO UPLAND PLANTS

- Upland plants require O_2 in soil air = 0.1L/L
- O_2 levels in atmosphere = 0.2L/L
- Methane and ethylene must not build up

REGULATION OF AVAILABLE OXYGEN

- **Soil macro-porosity**
  - Affected by texture and structure
- **Soil water content**
  - Affected by proportion of porosity filled with air
- **O_2 consumption** by respiring organisms



SOIL AERATION IN THE FIELD

- ***Poor soil aeration refers to a condition in which the availability of O_2 in the root zone is insufficient to support optimal growth of plants and microorganisms***

SOIL AERATION IN THE FIELD

- Problem when 80-90% of pore space is filled with water

- Provides little pore space for air

EXCESS MOISTURE HAMPERS SOIL AERATION

- Block pathways for gas exchange with atmosphere

- Compaction has the same effect, even if soil is not wet

EXCESS MOISTURE

- **Water saturated or waterlogged** – nearly all soil pores are filled with water
  - Wetlands
  - Depressions
  - Flat areas on upland sites
  - Well-drained areas with excessive water

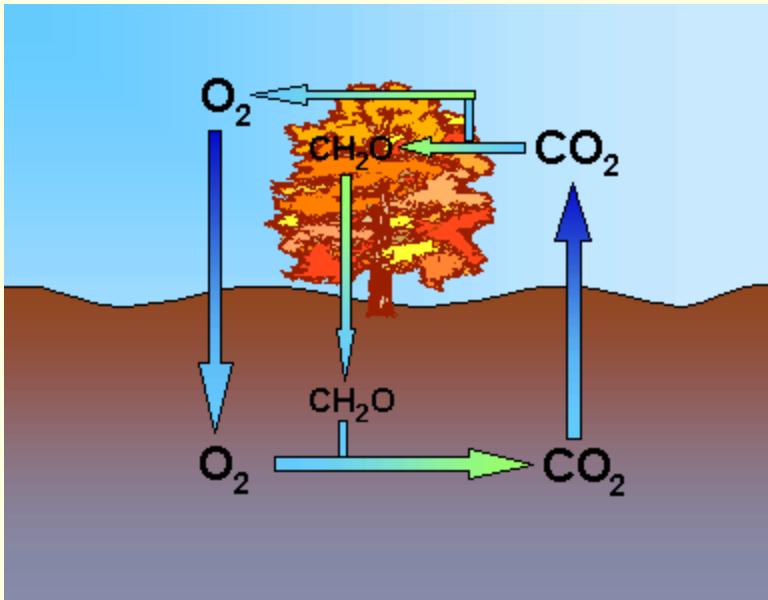
EXCESS MOISTURE

- **Hydrophytes** – plants adapted to live in waterlogged soils
  - Rice
  - Eastern gamma grass
  - Marsh grass
  - Bald cypress
  - Mangroves

HYDROPHYTES

GASEOUS INTERCHANGE

- **Oxygen** will move from atmosphere to soil
- **Carbon dioxide** and **water vapor** move from soil to atmosphere

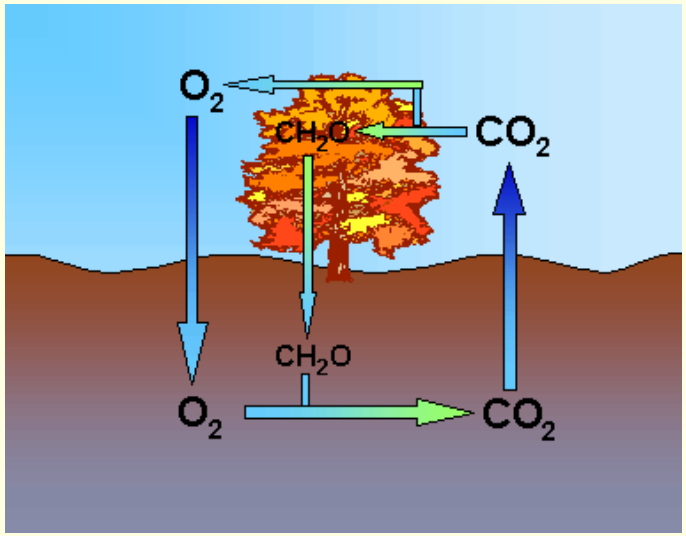


GASEOUS COMPOSITION OF SOIL AIR

- **Oxygen**
  - **Atmosphere:** 21% O_2; 0.035% CO_2; 78% N_2
  - **Soil air:** < 21%O_2; > 0.035% CO_2; 78% N_2
- **Anaerobic** – lack of oxygen in soil environment

GASEOUS COMPOSITION OF SOIL AIR

- **Carbon dioxide**
  - **Atmosphere:** 0.035% CO_2
  - **Soil air:** 0.35%CO_2
- **When CO_2 levels reach 10%, it may be toxic to plants**



GASEOUS COMPOSITION OF SOIL AIR

- **Soil water vapor is higher in the soil** than atmosphere
- **Methane** and **hydrogen sulfide** higher in waterlogged soils
- **Ethylene** can be toxic to plant roots

AIR-FILLED POROSITY

- **Microbial activity and plant growth are severely inhibited when:**
  - Air-filled porosity < 20% of pore space or 10% of total soil volume
- ***Oxygen diffuses 10,000 times faster through air-filled pores than water-filled pores***

SOIL AERATION

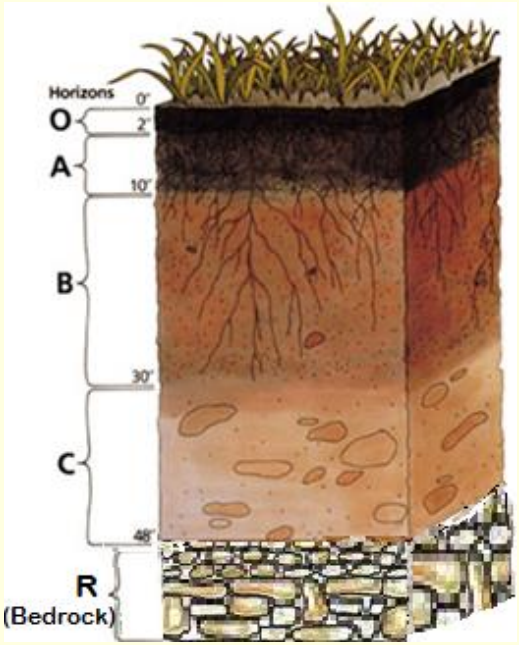
- ***"Soil aeration helps determine the specific chemical species present and, in turn, the availability, mobility, and possible toxicity of various soil elements"***

RATES OF RESPIRATION

- Oxygen and carbon dioxide levels are dependent on microbial activity
- Incorporation of organic matter affects respiration rates
- Respiration by plants roots are involved
- Respiration rate increases with temperature

SOIL HETEROGENEITY

- Subsoils more oxygen deficient than topsoils
- Total pore space is lower in deeper horizons



SOIL HETEROGENEITY

- **Large macropores**
  - Well-drained soils have localized areas of poor aeration
  - Saturated soils have opposite effect
- **Plant Roots**
  - May reduce or increase O_2 concentration
  - In poorly drained soils, roots may deplete O_2 levels

SEASONAL DIFFERENCES

- **Oxygen exchange is low in spring**
  - Soils are wetter and cooler
- **Gas exchange is higher in summer**
  - Soils are dryer and warmer

ECOLOGICAL EFFECTS OF SOIL AERATION

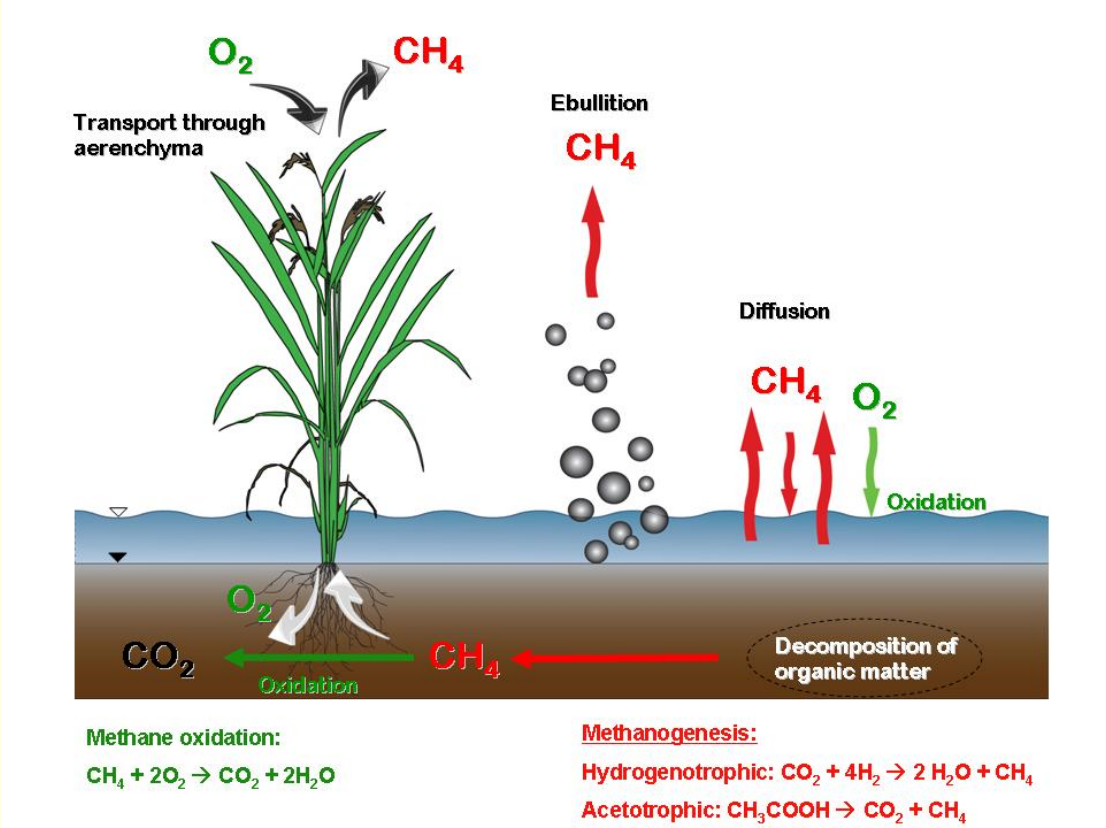
- **Rate of breakdown of organic matter**
  - Slower in poorly drained soils
  - Build up of gases which can be toxic to plants

ECOLOGICAL EFFECTS OF SOIL AERATION

- **Soil colors**
  - Well-oxidized soils are red, yellow, and reddish brown
  - Streaked soils indicate lack of uniform drainage

METHANE PRODUCTION IN SOILS

- Produced by a reduction of CO_2
- Common in wetlands and rice paddies



EFFECTS ON HIGHER PLANTS

- Root growth is curtailed
- Absorption of nutrients and water is decreased
- Toxic inorganic compounds are formed

AERATION AND SOIL AND PLANT MANAGEMENT

- Container grown plants suffer from overwatering
  - Mineral soil makes up about 1/3 of potting mixes
- Young trees and newly transplanted trees must be protected from **water-logging**

AERATION AND SOIL AND PLANT MANAGEMENT

- Adding fill to mature tree root zones can result in suffocation
- Compacted areas due to foot traffic may need to be core aerified

SOIL TEMPERATURES

PROCESSES AFFECTED BY SOIL TEMPERATURE

PROCESSES AFFECTED BY SOIL TEMPERATURE

- Physical processes
- Biological processes
- Chemical processes

PROCESSES AFFECTED BY SOIL TEMPERATURE

- **Most plants have a narrow range of soil temperatures that are optimum and affects:**
  - Yield
  - Plant life cycles
  - Plant growth

PROCESSES AFFECTED BY SOIL TEMPERATURE

- **Seed germination**
  - Crop plants
  - Cool and warm season weeds
  - **Vernalization** – period of cold temperature to stimulate germination or breaking of dormancy

PROCESSES AFFECTED BY SOIL TEMPERATURE

- **Root functions**
  - Nutrient and moisture uptake are slowed in cool soils

  - **Winter burn or physiological drought**

PROCESSES AFFECTED BY SOIL TEMPERATURE

- **Microbial processes**
  - **Biological Zero:** Temperature at which activity ceases (below 40^{o}F)
  - Respiration doubles for each 10^{o}C rise
  - Optimum range is 80 - 100^{o}F

PROCESSES AFFECTED BY SOIL TEMPERATURE

- **Freezing and thawing**
  - Alters physical structure of the soil

- **Frost heaving** – forcing of objects upward in soil due to freezing and thawing
  - Silts and sands are more susceptible
  - Clay soils are less susceptible

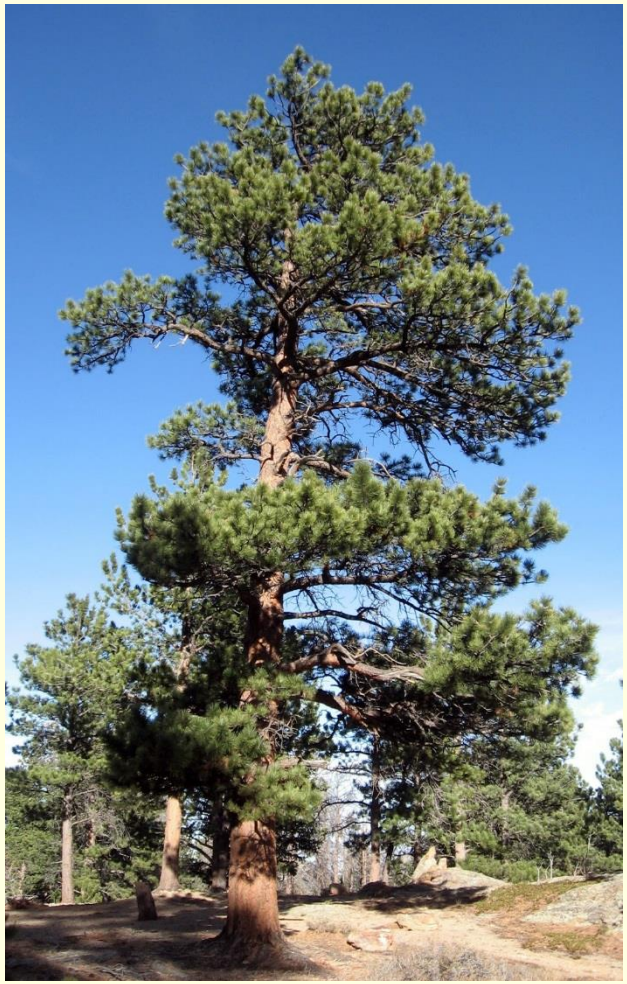
SOIL HEATING BY FIRE

- One of the major disturbances in nature

- Distillation of organic matter fractions leading to **hydrophobic** soil conditions

- Affect germination of seeds of **“fire pines”**

THE “FIRE PINES”
Ponderosa and Jack Pines



ABSORPTION AND LOSS OF SOLAR ENERGY

- **Albedo** – fraction of incident radiation reflected by land surface
  - 0.1 – 0.2 for rough, dark colored surfaces
  - > 0.5 for smooth, light colored surfaces
  - Darkest soils are usually the wettest and slower to warm up
- **Aspect** – direction of slope
  - Rays hitting perpendicular to earth's surface will heat the soil faster

ABSORPTION AND LOSS OF SOLAR ENERGY

- **Soil cover**
  - Bare soils warm more quickly and cool more rapidly than covered soils
  - Frost penetration is greater in bare soils compared to covered soils

MAXIMUM SOIL TEMPERATURES FOR FOUR TYPES OF SURFACES

SURFACE	MAX.TEMP.	MAX. TEMP.
	Day (ºC)	**Night (ºC)**
Turf	31 (88ºF)	24 (75ºF)
Dry, bare soil	39 (102)	26 (79)
Brown grass	52 (126)	27 (80)
Synthetic turf	70 (160)	29 (84)

THERMAL PROPERTIES OF SOILS

- Dry soils heat up more easily compared to wet soils

- **Specific heat (heat capacity)** – heat capacity per unit mass
  - Pure water = 1.00 cal/g
  - Dry soil = 0.2 cal/g

THERMAL PROPERTIES OF SOILS

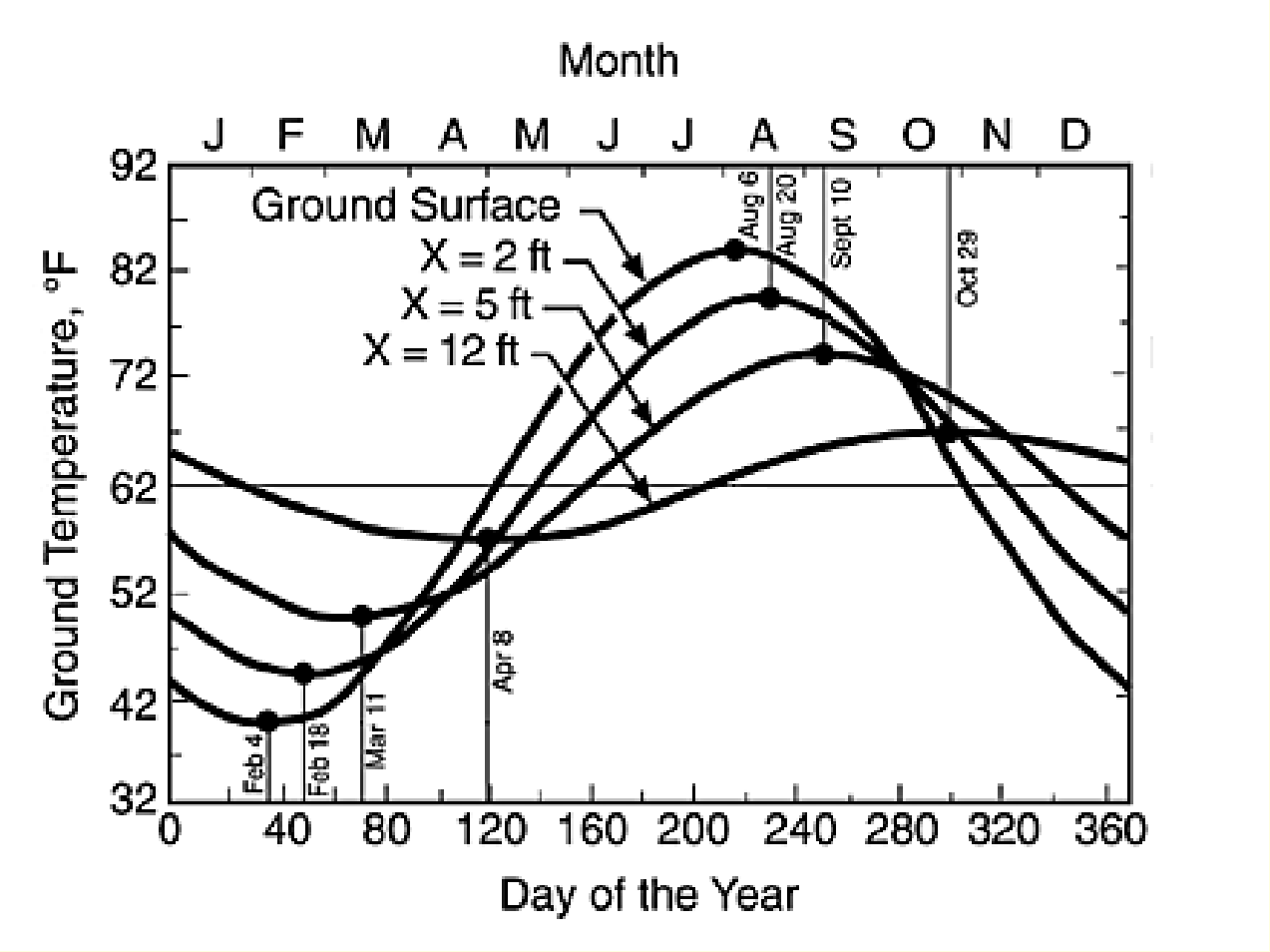
- **Heat of vaporization** – heat required to evaporate water from a soil surface
  - 540 kilocalories/kg

- Low temperature of wet soils in spring is due to evaporation and high specific heat

VERTICAL AND SEASONAL TEMPERATURE CHANGES

- Surface soils vary more with air temperature
- Sub-soils lag behind surface soil and air temperatures
- Surfaces soils respond to warming in spring while deep sub-soils lag behind responding to cold-like winter weather

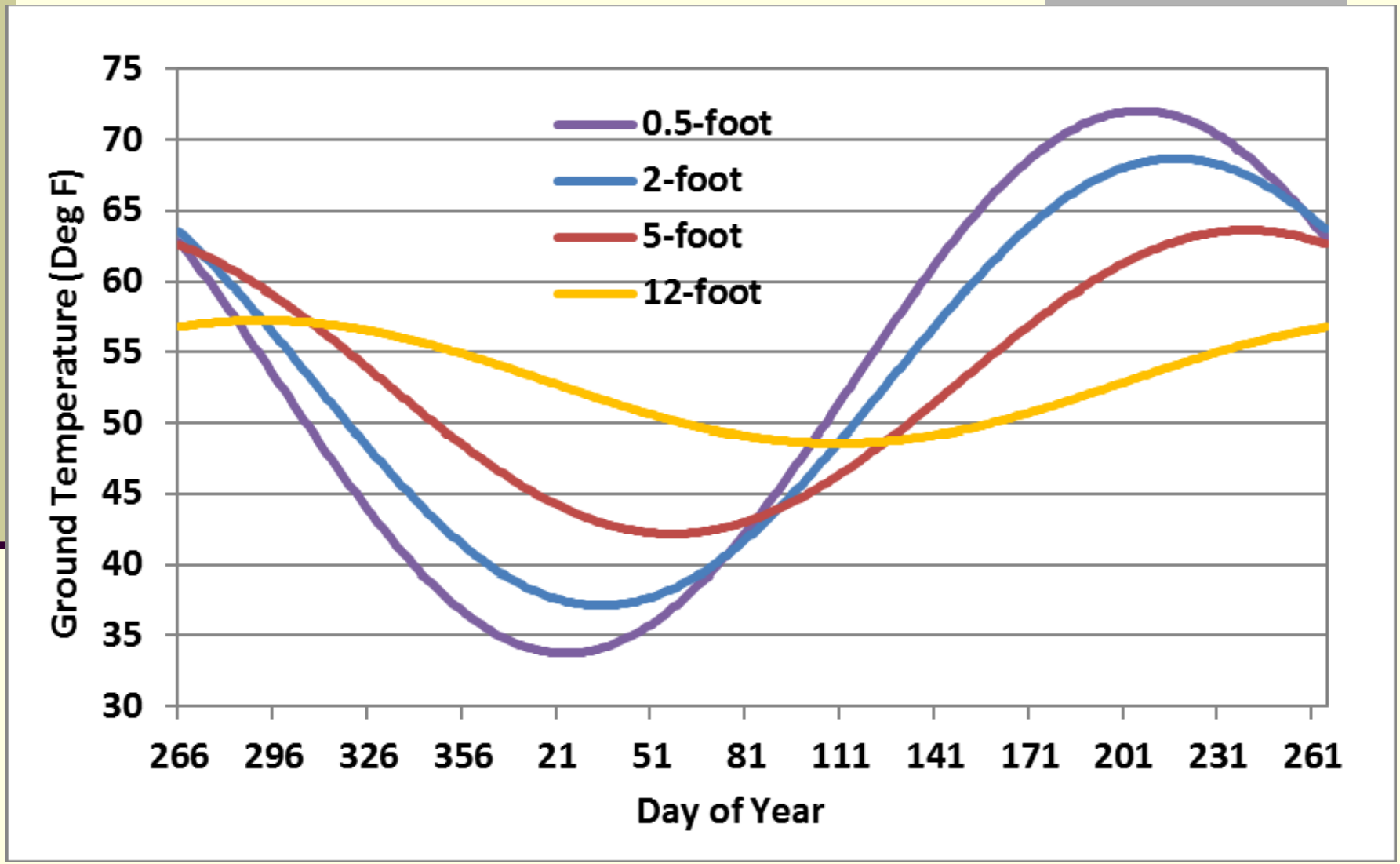
SOIL TEMPERATURES AND DEPTH



DAILY VARIATIONS

- Surface soil temperatures usually lag behind air temperature maximums
- Temperature change is less at greater soil depths
- Lower subsoil show very little daily and/or weekly fluctuations

SOIL TEMPERATURES AND DEPTH



FACTORS AFFECTING SOIL TEMPERATURE CONTROL

- Cover crops or mulch on the soil

- Practices that reduce soil moisture

FACTORS AFFECTING SOIL TEMPERATURE CONTROL

- **Organic mulches and plant residue** management
  - Mulches buffer extremes in soil temperatures

- **Plastic mulches**
  - Used in vegetable production to increase soil temperature

EFFECT OF MULCH AND GROUND COVERS ON SOIL TEMPERATURES

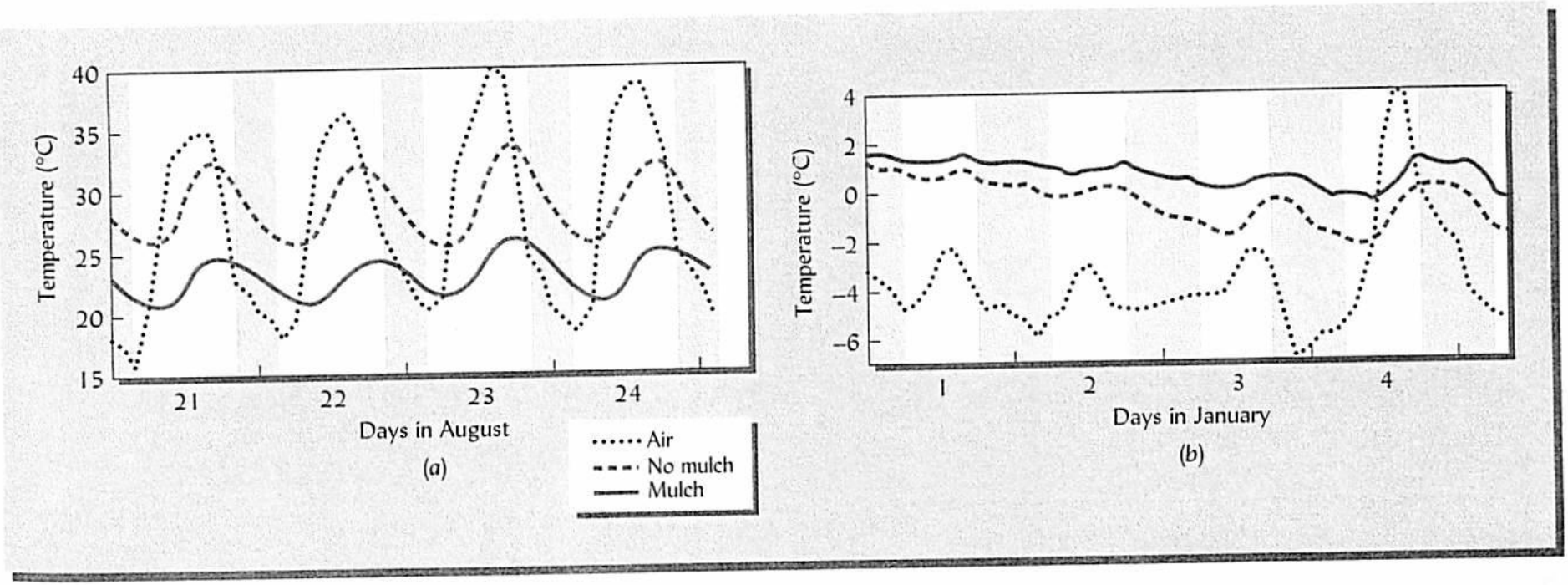
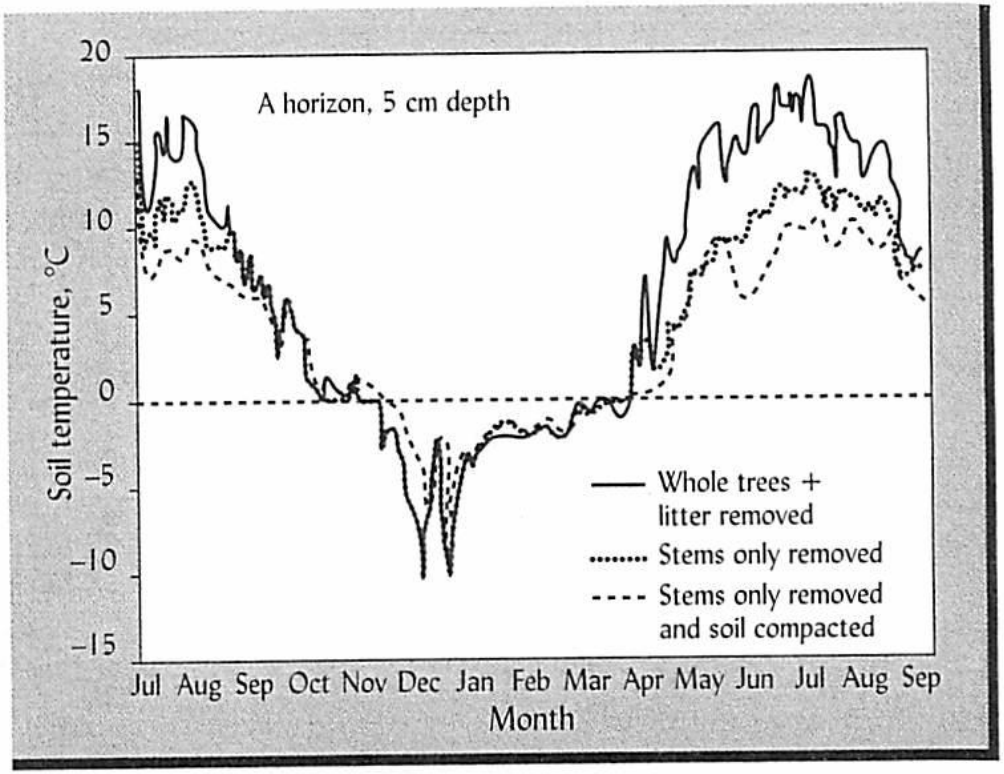


Figure 7.25
(a) *Influence of straw mulch* (8 tons/ha) *on air temperature at a depth of 10 cm during an August hot spell in Bushland, TX. Note that the soil temperatures in the mulched area are consistently lower than where no mulch was applied.* (b) *During a cold period in January, the soil temperature was higher in the mulched than in the unmulched area. The shaded bars represent nighttime.*
[Redrawn from Unger (1978); used with permission of American Society of Agronomy]

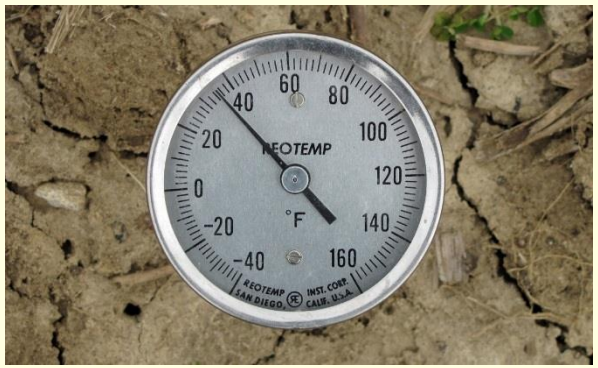
EFFECT OF LEAF LITTER ON SOIL TEMPERATURES

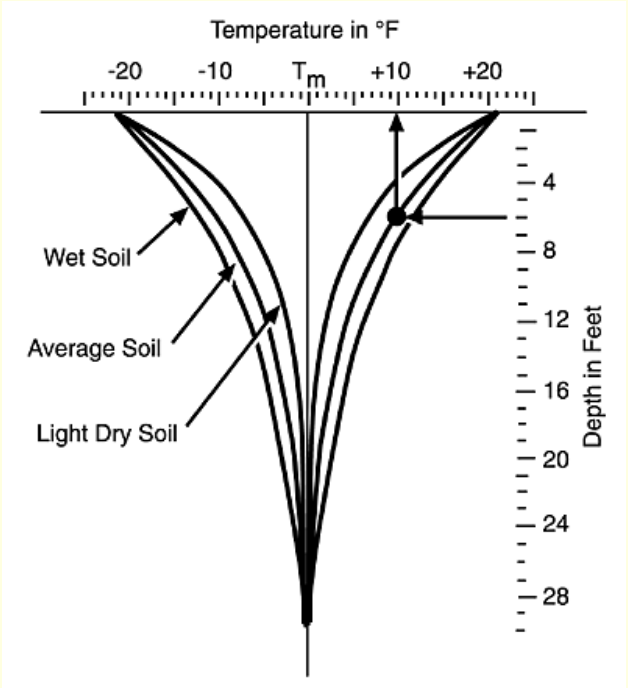
Figure 7.26
Soil temperature in an aspen-spruce boreal forest after two levels of harvest and soil compaction. One harvest procedure removed only the stems (tree trunks) with branches and foliage left on the soil, while a second procedure removed whole trees and stripped woody materials and litter to expose the mineral soil (this was done to simulate the kind of damage often inflicted by poorly managed harvest equipment). The soils were either left undisturbed during harvest, or they were severely compacted. The compacted treatment is shown only for the whole-tree removal procedure as compaction did not affect soil temperature where harvest removed only tree trunks. Exposure of the mineral soil A horizon resulted in much warmer temperatures in summer and somewhat colder soil in winter. Compaction of this soil mainly slowed warming in summer, partly because of a higher water content (and therefore a higher heat capacity). The Aquepts (Luvic Gleysols in the Canadian soil classification) at this site in British Columbia included about 20–30 cm of silt loam material over a clay loam. [From Tan et al. (2005)]



SOIL TEMPERATURE CONTROL

- **Moisture control**
  - Poorly drained soils that are wet in spring are 3-6^{o}C lower than well-drained soils
  - Installation of drainage systems or ridging systems can help increase warming of soils in spring





SUMMARY

- Soil aeration – the process
- Means of characterizing soil aeration
- Factors affecting soil aeration
- Ecological effects of soil aeration
- Aeration in relation to soil and plant management

SUMMARY

- Processes affected by soil temperature
- Absorption and loss of solar energy
- Thermal properties of soils
- Soil temperature control

END OF PRESENTATION