Bioecology
Module: Soil Science

Lecture 7.
Thermal properties of soils. Soil temperature. Soil air (Gaseous exchange)

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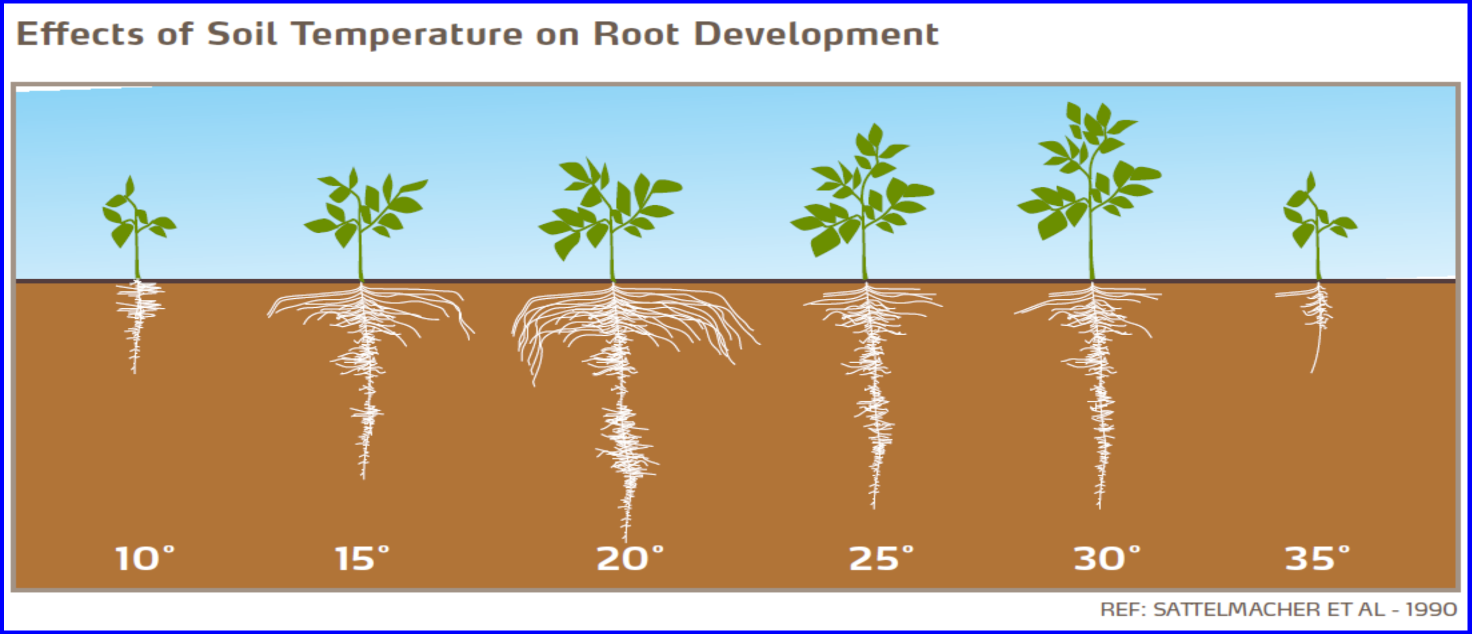
Thermal properties of soils

The thermal properties of soils influence how energy is partitioned in the soil profile. While related to soil temperature, it is more accurately associated with the transfer of heat throughout the soil, by radiation, conduction and convection.

Soil temperature is an important plant growth factor. Soil temperature affects plant growth directly and also indirectly by influencing moisture, aeration, structure, microbial and enzyme activities, rate of organic matter decomposition, nutrient availability and other soil chemical reactions.



Thermal properties of soils

Specific crops are adapted to specific soil temperatures. Apple grows well when the soil temperature is about 18^0C, maize 25^0C, potato 16 to 21^0C, and so on.

Vegetable	Soil Temperature for seed Germination [1]			Time Required for growing Plants for Field Transplanting [4]
	Optimum Range (°F)	Day [2] (°F)	Night (°F)	Time (weeks)
Asparagus	60 - 85	70 - 80	65 - 70	8 - 10
Broccoli	68 - 86	60 - 70	50 - 60	5 - 7
Brussel Sprouts	75	60 - 70	50 - 60	5 - 7
Cabbage	45 - 95	60 - 70	50 - 60	5 - 7
Cauliflower	45 - 85	60 - 70	50 - 60	5 - 7
Celery	60 - 70	65 - 75	60 - 65	10 - 12
Corn, Sweet	60 - 95	70 - 75	60 - 65	3 - 4
Cucumber	60 - 95	70 - 75	60 - 65	3 - 4
Eggplant	75 - 90	70 - 80	65 - 70	6 - 8
Lettuce	40 - 80	55 - 65	50 - 55	5 - 7
Muskmelon	75 - 95	70 - 75	60 - 65	3 - 4
Okra	85 - 95 [3]	70 - 75	65 - 70	4 - 6
Onion	50 - 95	60 - 65	55 - 60	10 - 12
Pepper	65 - 95	65 - 75	60 - 65	6 - 8
Squash / Pumpkin	70 - 95	70 - 75	60 - 65	3 - 4
Tomato	60 - 85	65 - 75	60 - 65	5 - 7
Watermelon	70 - 95	70 - 80	65 - 70	3 - 4

Soil factors

a) **Thermal (Heat) capacity of soil:** ***Heat capacity*** is the amount of energy required to raise the temperature by 1^0C. When it is expressed per unit mass (Calories per gram), then it is called as ***specific heat***. The specific heat of water is 1.00 cal/g where the specific heat of a dry soil is 0.2 cal/g. Increasing water content in soil increases the specific heat of the soil and hence a dry soil heats up quickly than a moist soil.

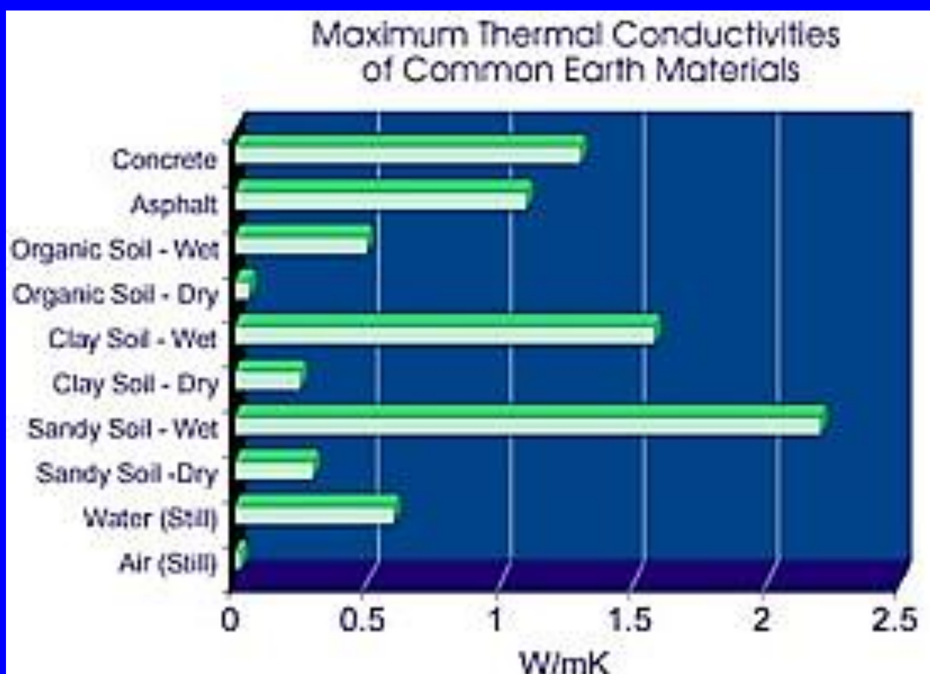
Material	Particle density (gm cm – 3)	Specific heat (cal gm^{-1} °C^{-1})
Quartz	2.65	0.19
Feldspar	2.55	0.20
Mica	2.81	0.21
Granite	2.65	0.19
Calcite	2.70	0.21
Hematite	5.10	0.16
Feric Oxide	5.00	0.15
Dolomite	2.85	0.23
Apatite	3.25	0.21
Kaolinite	2.40	0.19
Humus	1.30	0.46
Water	1.00	1.00
Ice (0°C)	0.92	0.50
Air	0.0012	0.25
Wood	0.90	0.42
Clay	2.27	0.22
Soil mineral fraction	2.65	0.18
Soil organic fraction	1.30	0.46
Soil solids	2.65	0.20

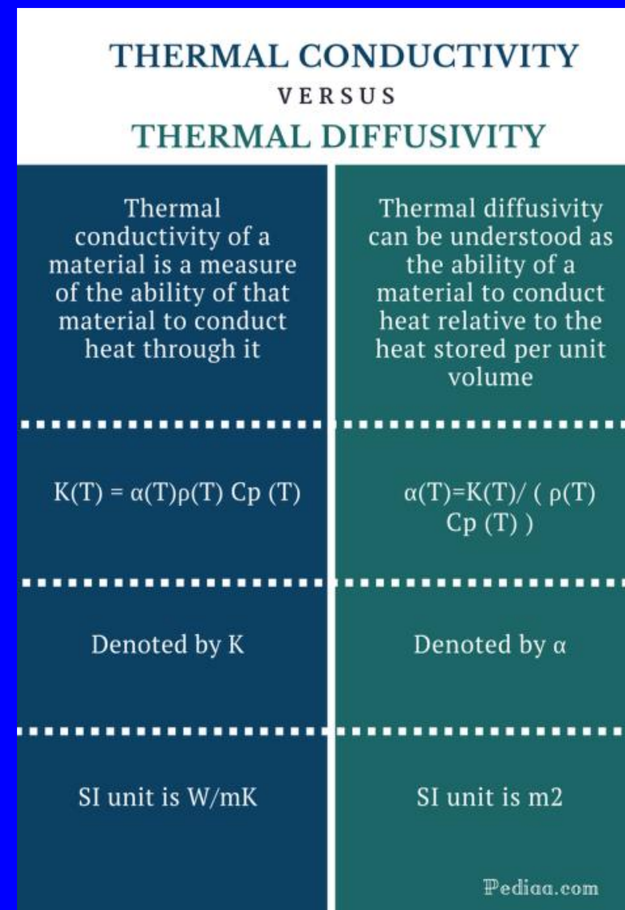
b) **Heat of vaporization**: The evaporation of water from soil requires a large amount of energy, 540 kilocalories/kg soil. Soil water utilizes the energy from solar radiation to evaporate and thereby rendering it unavailable for heating up of soil. Also the thermal energy from soil is utilized for the evaporation of water, thereby reducing the soil temperature. This is the reason that surface soil temperatures will be sometimes 1 to 6^0C lower than the sub-surface soil temperature. That is why the specific heat of a wet soil is higher than dry soil.

Soil factors

c) **Thermal conductivity and diffusivity**: This refers to the movement of heat in soils. In soil, heat is transmitted through conduction. Heat passes from soil to water about 150 times faster than soil to air. So the movement of heat will be more in wet soil than in dry soil where the pores will be occupied with air.

Thermal conductivity of soil forming materials is 0.005 thermal conductivity units, and that of air is 0.00005 units, water 0.001 units. A dry and loosely packed soil will conduct heat slower than a compact soil and wet soil.





Soil factors

d) **Biological activity**: Respiration by soil animals, microbes and plant roots evolve heat. More the biological activity more will be the soil temperature.

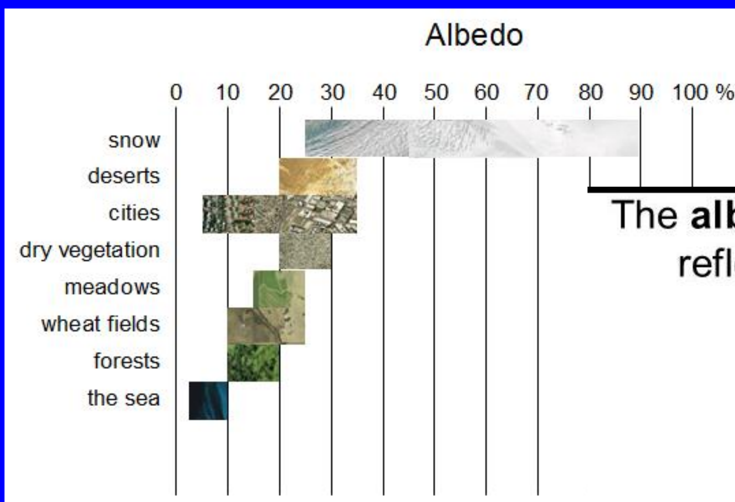
e) **Radiation from soil**: Radiation from high temperature bodies (Sun) is in short waves (0.3 to 2.2 μ) and that from low temperature bodies (soil) is in long waves (6.8 to 100 μ) Longer wavelengths have little ability to penetrate water vapour, air and glass and hence soil remains warm during night hours, cloudy days and in glass houses.

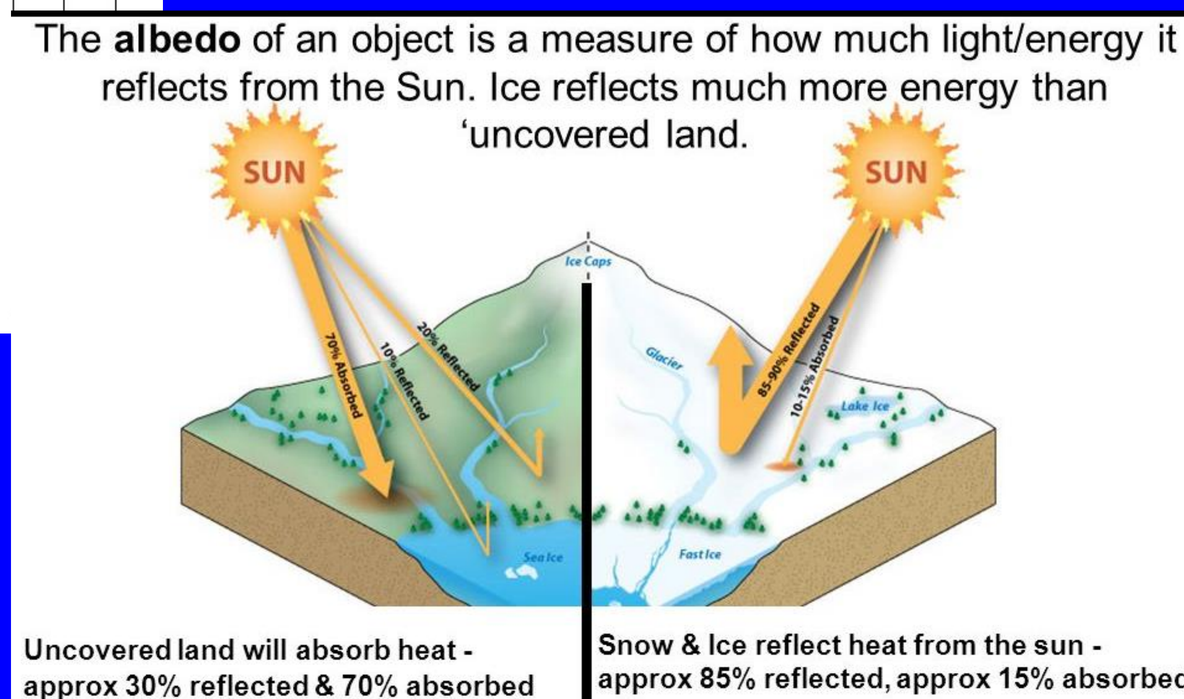
f) **Soil structure, texture and moisture:** Compact soils have higher thermal conductivity than loose soils. Natural structures have high conductivity than disturbed soil structures. Mineral soils have higher conductivity than organic soils. Moist soil will have uniform temperature over depth because of its good conductivity than dry soils.

g) **Soluble salts:** Indirectly affects soil temperature by influencing the biological activities, evaporation etc.

Soil factors

h) **Soil colour**: Colour is produced due to reflection of radiation of specific wavelengths. Dark coloured soils radiate less heat than bright coloured soils. The ratio between the incoming (incident energy) and outgoing (reflected energy) radiation is called ***albedo.*** The larger the albido, the cooler is the soil. Rough surfaced soil absorbs more solar radiation than smooth surface soils.





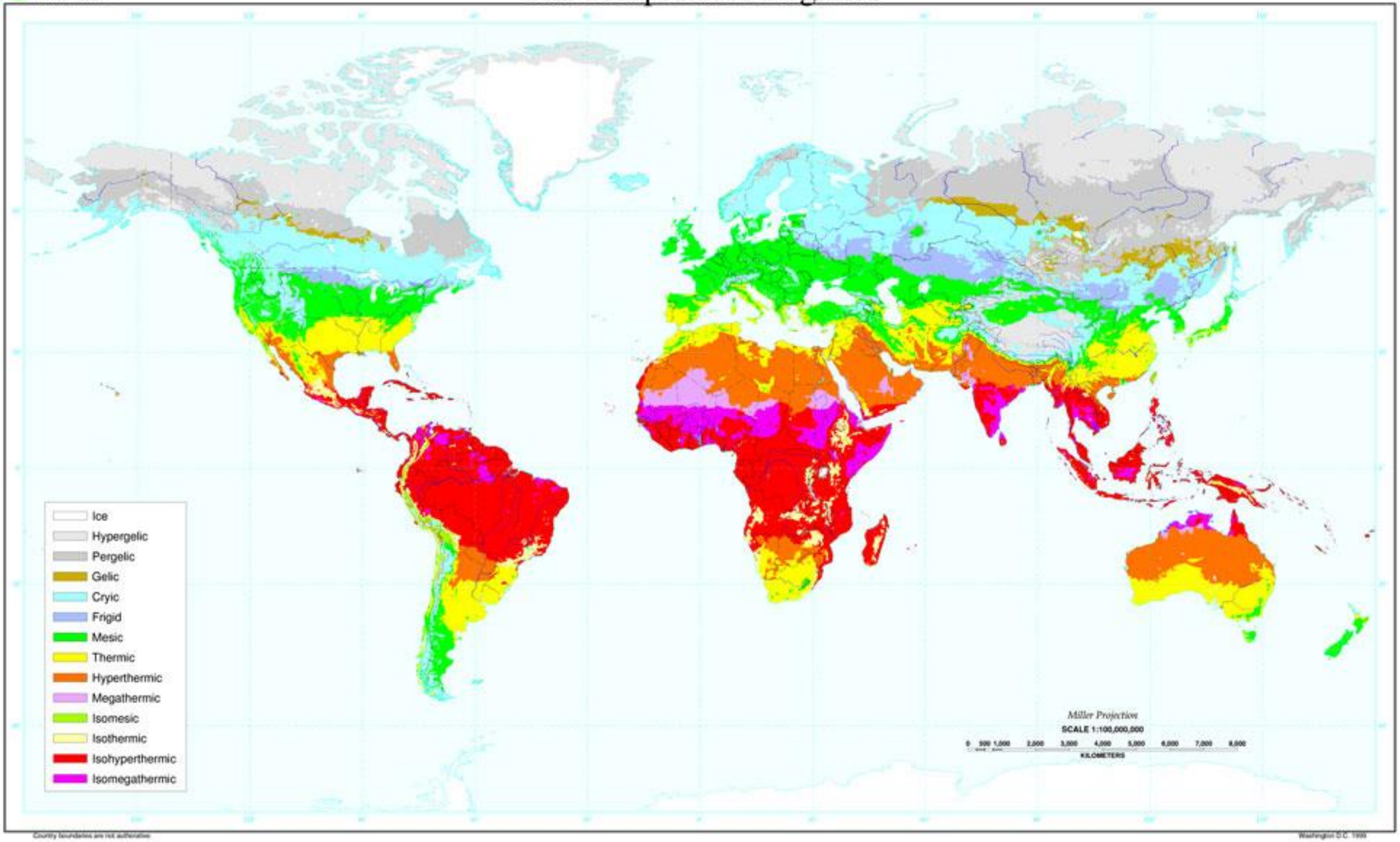
Soil temperature regimes

In soil taxonomy, soil temperature regimes are based on mean annual soil temperatures. Soil temperatures are taken at a depth of 50 cm from the soil surface, using the Celsius (centigrade) scale.

Soil Temperature Class	Temperature Range
Frigid	Lower than 8° C
Mesic	8° C to 15° C
Thermic	15° C to 22° C
Hyperthermic	22° C or higher

U.S. Dept. of Agriculture
Natural Resources Conservation Service
Soil Survey Division
World Soil Resources

Soil Temperature Regimes



Country boundaries are not authoritative

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Soil air

Soil air is a continuation of the atmospheric air. It is constant state of motion from the soil pores into the atmosphere and from the atmosphere into the pore space. This constant movement or circulation of air in the soil mass resulting in the renewal of its component gases is known as ***soil aeration.***

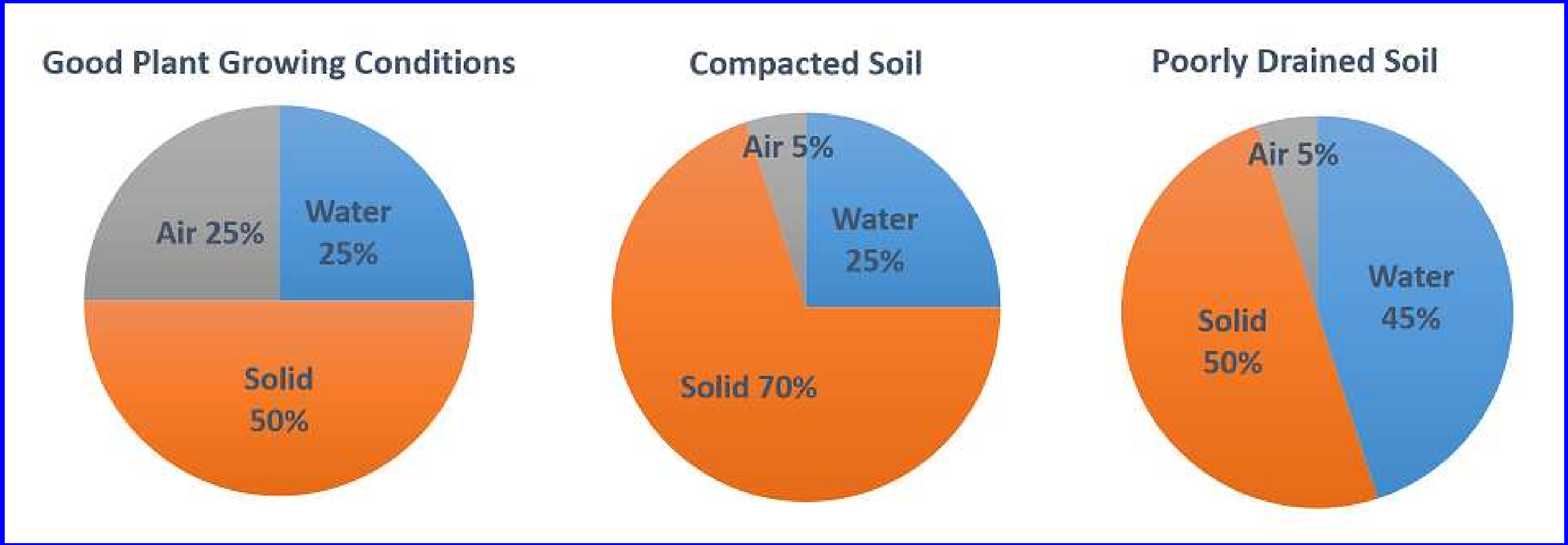
Composition of soil and atmospheric air (Percentage by volume)

	Nitrogen	Oxygen	Carbon dioxide
Soil air	78.8	10-20	11 - 1
Athmospheric air	78.8	20.95	0.03

Factors Affecting the Composition of Soil Air:

1. **Nature and condition of soil**: The quantity of oxygen in soil air is less than that in atmospheric air. The oxygen content of the air in lower layer is usually less than that of the surface soil. Light texture soil or sandy soil contains much higher percentage than heavy soil.

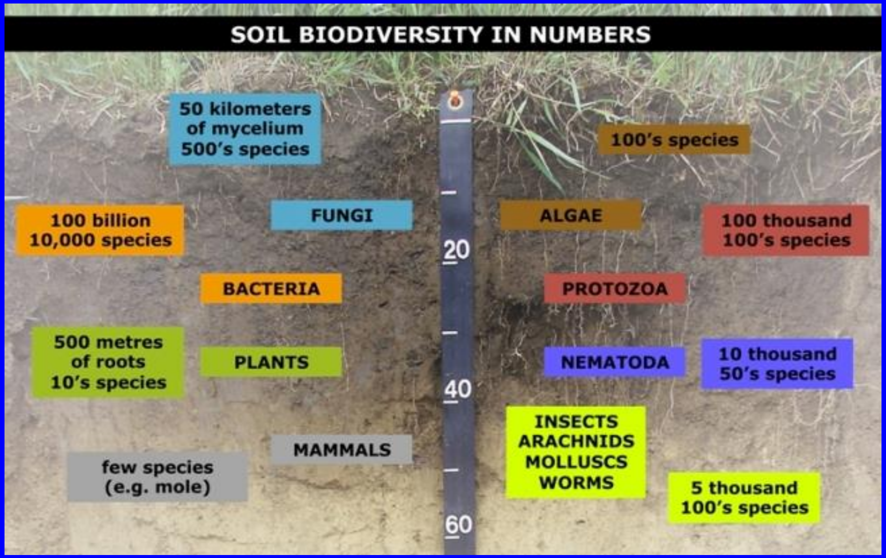
2. **Type of crop:** Plant roots require oxygen, which they take from the soil air and deplete the concentration of oxygen in the soil air. Soils on which crops are grown contain more CO_2 than fallow lands. The amount of CO_2 is usually much greater near the roots of plants than further away. It may be due to respiration by roots.



Factors Affecting the Composition of Soil Air:

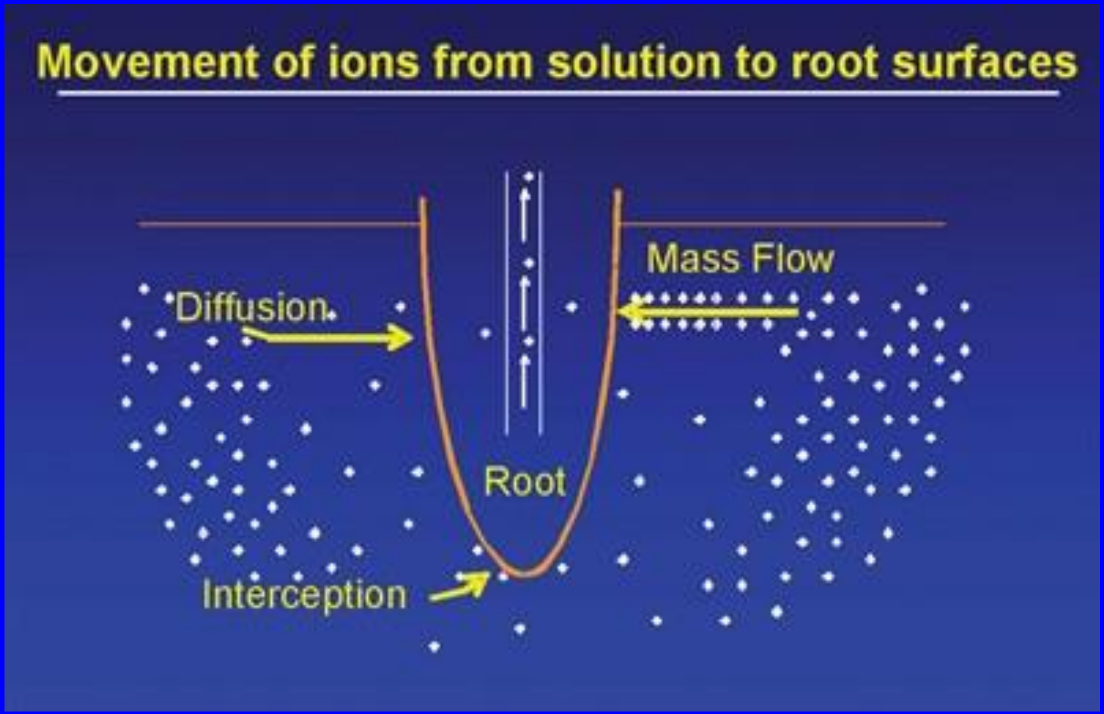
3. **Microbial activity:** The microorganisms in soil require oxygen for respiration and they take it from the soil air and thus deplete its concentration in the soil air. Decomposition of organic matter produces CO_2 because of increased microbial activity. Hence, soils rich in organic matter contain higher percentage of CO_2.

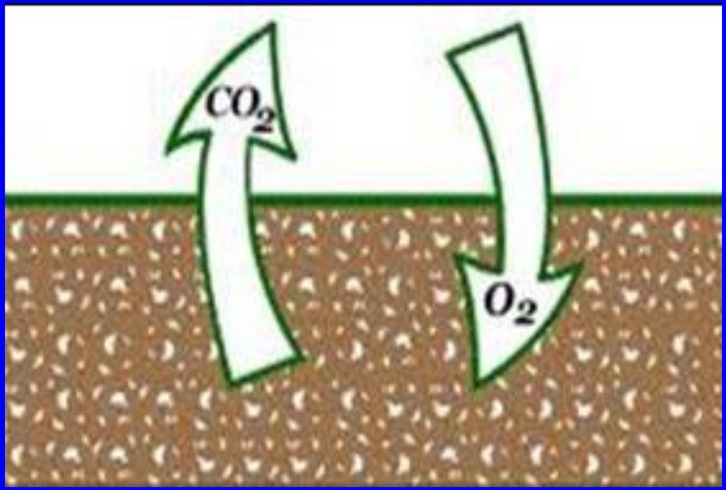
4. **Seasonal variation:** The quantity of oxygen is usually higher in dry season than during the monsoon. Because soils are normally drier during the summer months, opportunity for gaseous exchange is greater during this period. This results in relatively high O_2 and low CO_2 levels.High temperature during summer season encourages microorganism activity which results in higher production of CO_2.



Exchange of Gases between Soil and Atmosphere

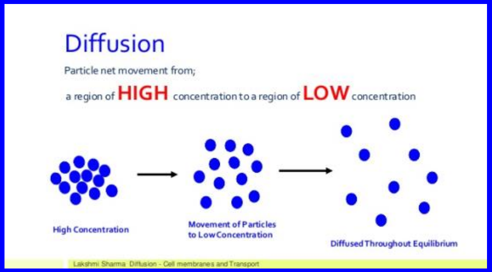
1. **Mass flow:** With every rain or irrigation, a part of the soil air moves out into the atmosphere as it is displaced by the incoming water. As and when moisture is lost by evaporation and transpiration, the atmospheric air enters the soil pores. The variations in soil temperature cause changes in the temperature of soil air. As the soil air gets heated during the day, it expands and the expanded air moves out into the atmosphere. On the other hand, when the soil begins to cool, the soil air contracts and the atmospheric air is drawn in.

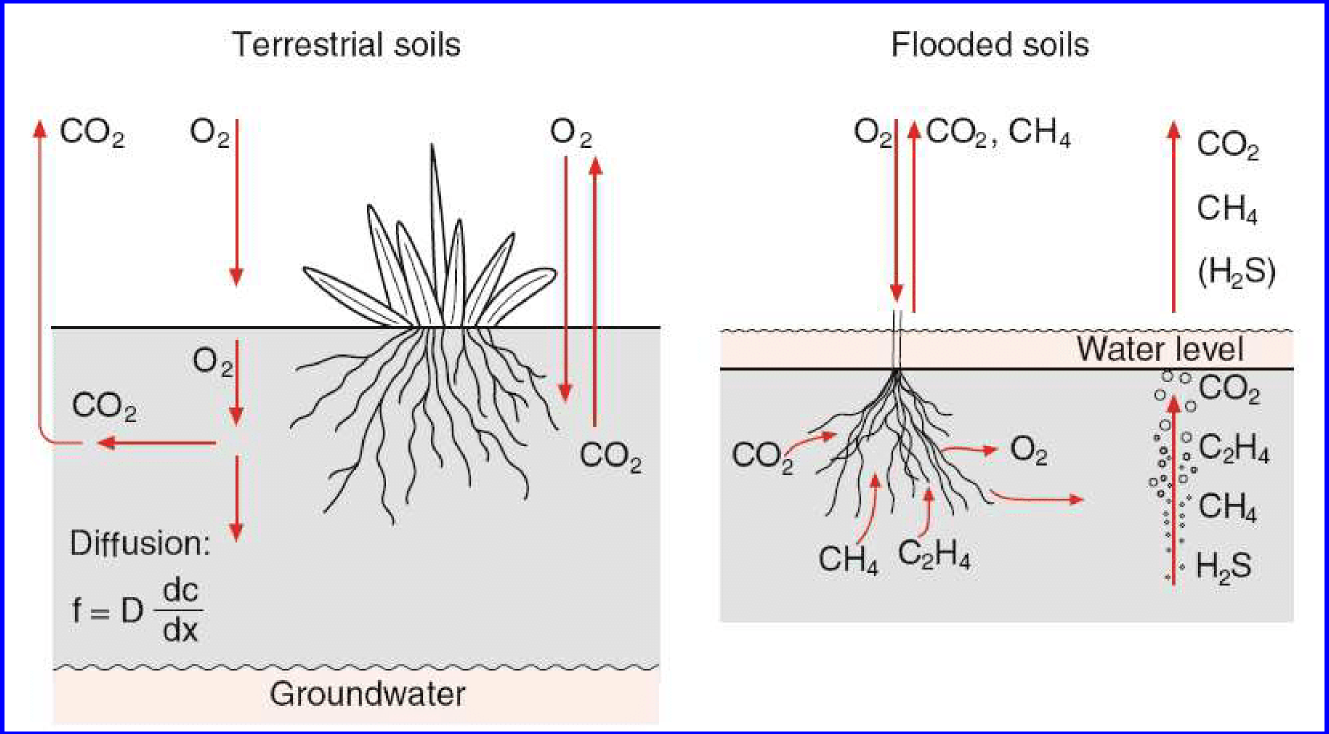




Exchange of Gases between Soil and Atmosphere

2. **Diffusion**: Most of the gaseous interchange in soils occurs by diffusion. Each of gases exerts its own partial pressure in proportion to its concentration. The movement of each gas is regulated by the partial pressure under which it exists. Diffusion allows extensive movement and continual change of gases between the soil air and the atmospheric air. Oxygen and carbon dioxide are the two important gases that take in diffusion.





Thank you for attention!