Soil Air and Temperature

I Soil Aeration

Oxygen is needed for aerobic respiration in soil.

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

CO_2 must also be removed.

Aeration is reduced due to excessive water and slow gas exchange with atmosphere. Gas exchange is principally by diffusion whereby gases move down a partial pressure gradient from higher to lower partial pressure. In the case of O_2, movement is from higher atmospheric partial pressure of O_2 to lower soil air partial pressure of O_2. The opposite is true for CO_2 and H_2O.

Measuring Soil Aeration

Although O_2 content may be measured or the O_2 diffusion rate determined, aeration is usually measured indirectly by the oxidation-reduction (redox) potential. Redox potential is a measure of the tendency of a substance to gain or lose electrons. The potential is for the half-reaction

reduced state $\Leftrightarrow$ oxidized state + n*e*

for which the redox potential is given by

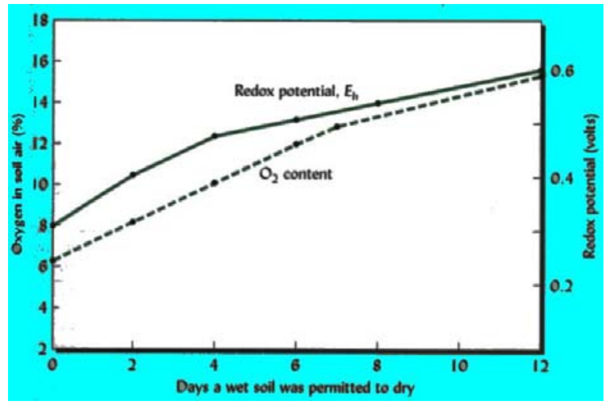
$Eh = E^o + (RT/nF) \ln([\text{oxidized}]/[\text{reduced}])$

For the half-reaction

$2H_2O \Leftrightarrow O_2 + 4H^+ + 4e$

$Eh = E^o + (0.059/4) \log(P_{O2}) - 0.059\ pH$

Eh decreases with decreasing partial pressure of O_2. Eh is also affected by pH.



Relationship between O_2 content and Eh.

Following a heavy rain the O_2 partial pressure in soil decreases due to interruption in supply of O_2 and continued root and microbial respiration. Aerobic respiration slows and anaerobic soil microorganisms that use other elements other than O_2 as terminal *e* acceptors in respiration become active. For example, certain microorganisms use oxidized iron

$Fe_2O_3 + 6H^+ + 2e \Leftrightarrow 2Fe^{2+} + 3H_2O$

The redox potential of soil in which Fe^{3+} is reduced to Fe^{2+} is lower than the Eh of an aerobic soil. Different microorganisms use a sequence of different terminal *e* acceptors besides Fe^{3+}

Oxidized	Reduced
NO_3^-	N_2
MnO_2	Mn^{2+}
Fe_2O_3	Fe^{2+}
SO_4^{2-}	S^{2-}
CO_2	CH_4

Soil Eh decreases along this sequence.

Factors Affecting Soil Aeration

Soil water content and drainage
Macroporosity
Organic matter
Depth in profile
Seasonal variations in respiratory demand

Effects of Poor Aeration

Anaerobic metabolism

Slower than aerobic. Less energy and different end products are obtained. Some of these end products are toxic to plants.

Reducing conditions

Affect availability of nutrients, including loss of NO_3^- by conversion to gaseous forms of nitrogen or increased solubility of iron as Fe^{2+}, possibly leading to toxicity. The CH_4 and N_2O produced under anaerobic conditions are greenhouse gasses.

Direct effects on plant growth

O_2 deficiency slows root respiration and reduces water and nutrient uptake.

Management of Soil Aeration

Surface and subsurface drainage
Choice of crops resistant to wet conditions

Situation with wetlands is opposite - preserve waterlogged conditions / low Eh.

II Soil Temperature

Affects rates of biological (particularly, plant growth and microbial processes), chemical and physical processes.

Factors Affecting Soil Temperature

Solar energy

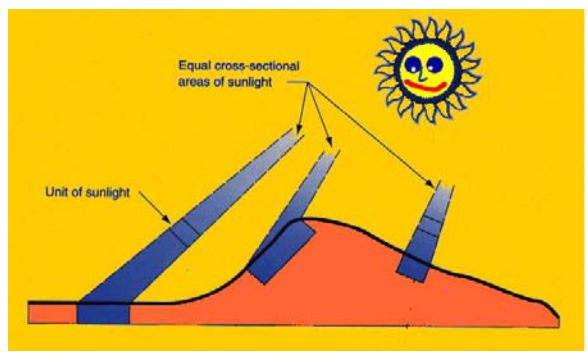
Amount of solar radiation absorbed by soil depends on soil color, slope and vegetative cover.

Color

Dark soils absorb more solar energy but these typically have a high water holding capacity due to high organic matter. As a result, the rate of temperature increase may be slow due to increased heat capacity and evaporative cooling.

Slope and aspect

Affect solar energy per unit area of soil surface.



Inclination with respect to solar radiation affects intensity.

Block incoming radiation and reduce emission from the soil.

Specific heat of soils

C (cal/g deg) total = specific heat of matrix and water

$C = (C_M\ mass_M + C_W\ mass_W)/mass_{M+W}$

Determines the amount of heat required to elevate soil temperature. The higher the specific heat, the greater the amount of heat that must be absorbed to raise the temperature a given number of degrees.

Heat of vaporization of water

H_{vap} = 540 cal/g

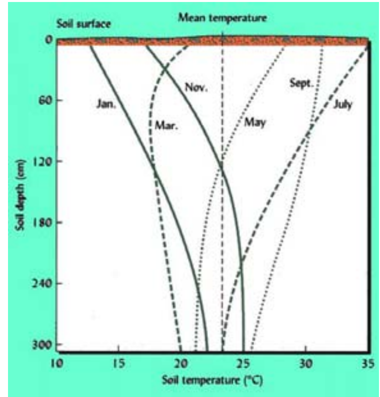
Energy for evaporation comes from solar radiation or soil. Evaporation tends to cool the soil and along with high specific heat of wet soil will slow warming.

Thermal conductivity

Heat flow is down a thermal gradient from relatively hot to relatively cold. However, for a given gradient, the rate of heat flow is controlled by the thermal conductivity -the more conductive the material, the faster the heat flow. In soils, the greater the bulk density, the greater contact between soil solids and the greater the thermal conductivity. Water improves thermal contact between soil solids and so increases the rate of heat transmission.

Temperature Variations with Depth

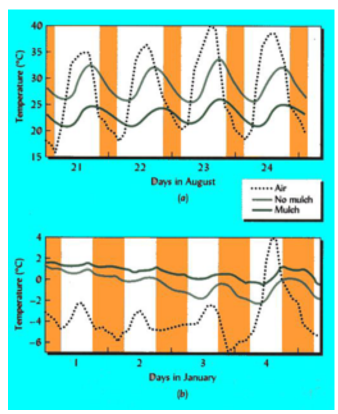
Subsurface temperatures lag behind changes in surface temperatures. This occurs on daily and yearly cycles. The variations (maximum - minimum) in subsurface temperatures are also less.



Seasonal variation in soil temperature with depth.

Soil Temperature Management

Control of soil water or use of surface cover
Surface and subsurface drainage
Crop residue or organic mulch reduce extremes in soil temperature fluctuations



Effect of mulch on soil temperature.