Soil Aeration and Temperature

ESS 210

Chapter 7
p 272-315

Soil aeration

• The ventilation of soil – rate of gas exchange
• Dependent upon:
  – Porosity
  – Water content
  – Oxygen consumption by organisms
• Saturated soil = anaerobic: $O_2$ has low solubility in $H_2O$ and slow rate of dissolution
• $O_2$ present = aerobic (oxic); absent = anaerobic

Soil air composition

• Air above soil: 21% $O_2$, 0.035% $CO_2$, 78% $N_2$
• Soil atmosphere: inverse relationship between $O_2$ and $CO_2$
  – $O_2$ ~ 20% at surface to < 5% in lower horizons
  – No $O_2$, anaerobic (typical of wet soils)
  – Carbon dioxide levels often 0.35% – 10x that of air
• Other gases:
  – $H_2O$ vapor (typically 100% relative humidity)
  – In strongly reduced soils: methane ($CH_4$), ethylene ($C_2H_4$), and hydrogen sulfide ($H_2S$) (toxic to plants if air exchange is too slow)

Redox potential

• $O_2$ readily accepts electrons from other elements; it is an oxidizer
  $\frac{1}{2}O_2 + H^+ + e^- \rightarrow \frac{1}{2}H_2O$
• Redox potential is dependent upon pH and electron acceptors
• Primary electron acceptors in soils (if $O_2$ absent):
  – $\frac{1}{2}NO_3^- + H^+ + e^- \rightarrow \frac{1}{2}NO_2^- + \frac{1}{2}H_2O$
  – $\frac{1}{2}Mn^{IV}O_2 + H^+ + e^- \rightarrow \frac{1}{2}Mn^{II} + H_2O$
  – $Fe^{III} + e^- \rightarrow Fe^{II}$
  – $\frac{1}{2}SO_4^{2-} + 5H^+ + 4e^- \rightarrow \frac{1}{2}H_2S + 2H_2O$

Factors Affecting Redox

• Drainage of macropores and soil macroporocity
• Soil respiration rates (is there food for bugs?)
• Subsoil more depleted of $O_2$ than topsoil
• Soil heterogeneity
  – Profile
  – Tillage
  – Macroporocity
  – Plant roots

Ecological Effects of Redox

• Breakdown of organic (crop, leaf litter, etc.) residues: organic matter accumulates in saturated soils → histic; in aerated soils → $CO_2 + H_2O$
• Absence of $O_2$, anaerobes take over: decomposition is slow and incomplete (partially decomposed organic compounds produced)
• How can you tell redox potential?
Redox Potential is Seen by:

- Soil color (Fe & Mn transformations; suboxic)
  - Gray (gleyed)
  - Mottles
  - Matrix color
- Gases (S & C transformations; anoxic)
  - H₂S (reduction of SO₄²⁻), mercaptans, etc.
  - Methane (reduction of CO₂)
- Vegetation
  - Plants vary in ability to tolerate poor aeration

Wetlands – Poorly Aerated Soils

- Soils that are water-saturated near the surface for prolonged periods when the soil temperature is high enough to result in anaerobic conditions (bugs active to deplete soil O₂)
  - Swamps, bogs, coastal (salt-affected) marshes, etc.
  - Histosols & histic epipedons
  - Frozen soils (Histels)

What is a wetland?

"Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water." (Cowardin et al., 1985)

Usually Defined by Three Characteristics:

- Vegetation:
  - More than 50% of the dominant species are hydrophytic plants (aerenchyma tissues typical)
- Hydrology:
  - Seasonally inundated and/or saturated for consecutive days > 12.5% of growing season
- Hydric soils (redoximorphic features in upper horizons)
  - Peraquic & aquic moisture regimes
  - Gley chroma (< 1)
  - Organic matter accumulation

Importance of Wetlands

- Flood-control
  - Temporary storage of excess water
  - >19 million acres of wetlands have been drained in the Upper Mississippi River Valley
  - Loss of 30 million acre-feet of storage
  - Restoration of 15% would have reduced flood stage at St. Louis in 1993 by 2 feet

Importance of Wetlands

- Water quality
  - Water movement VERY slow
  - Sediments settle
  - Nutrients utilized by plant life
  - Effective pollution filter (agricultural and urban)
- Groundwater recharge
- Shoreline protection
Importance of Wetlands

• Maintenance of biodiversity
• Net primary productivity is higher in wetlands than any other ecosystem
• Spawning grounds, migratory bird habitat, amphibians, insects, ...
• ~40 % of all endangered species & ⅓ of all birds in US depend on wetlands

Soil T-Affected Processes

• Plant growth rates
• Seed germination
• Root functions
• Microbial processes
  – < 5 °C not much happens
  – Biological activity doubles with every 10 °C increase
• Freezing and thawing
  – Ice lenses
  – Frost heaving

Absorption and Loss of Solar Energy

• **Albedo**: the fraction of incident radiation that is reflected from the land surface
• Aspect: how the land faces the sun – south facing vs. north facing
• Rain
  – Summer rains cool the soil
  – Spring rains warm the surface but, overall, make the soil cooler and harder to warm (high specific heat of water determines the rate at which soil warms in the spring)

Soil Temperature Control

• Mulches
• Residues
• Shading
• Moisture control