SOIL WATER

LECTURE 4
SOIL WATER

- The variable amount of water contained in a unit mass or volume of soil and the energy state of water in the soil are important factors affecting the growth of plants.

- The liquid phase properties of a soil, such as water content, and how water passes through the solum, are very important factors that need to be considered for plant growth and other management strategies, as they affect the physical properties of the soil.
Saturated and Unsaturated Flows

- Water flow in soils may occur in both unsaturated and saturated conditions.
- Water moves in the soil according to the difference in potential (water flows from a higher potential to the state of lower potential, i.e. drier soil).
- This potential difference is called the hydraulic conductivity of soil.
• The flow rate of water depends on gradients in soil water potential ($\Psi_m$) caused by differences in height, pressure, dissolved solutes and soil wetness.

• Water flows faster in large than in smaller pores and in thicker water films than thin.

• This is because there is less friction and attraction to surfaces and water flow is less interrupted in wet soil.
Saturated Flow

- Saturated flow occurs when soil pores are completely filled with water.
- Saturated flow conditions occur in aquifers (water-bearing sediments and rock layers), in flooded soil and in lower horizons of soil with limited drainage.
- The upper horizons of a well drained soil above stratified layers of clay and top soil horizons can also be saturated immediately following a heavy rainfall event or irrigation.
- As gravitational water partly drains from large water filled pores and the water is replaced by large air pockets, water flow rate is greatly reduced.
• The driving force for water flow in saturated flow is through the matric potential gradient (i.e. $\Psi_m$).
• Movement will therefore be in the direction of moist soil to dry soil and from thick moisture- to thin Moisture films.
Unsaturated Flow

- The pore space is only partly filled with water, resulting in a soil water pressure smaller than atmospheric pressure.

- Unsaturated flow is generally rapid through fine sand or well aggregated loams (medium sized pores) and slower through very fine and poorly aggregated clayey soil (very small pores).
Hydraulic Conductivity and Infiltration

- **Hydraulic conductivity** of a soil is a measure of the soil's ability to transmit water when submitted to a hydraulic gradient.

- Hydraulic conductivity, symbolically represented as $K$, is a property of soil that describes the ease with which water can move through pore spaces.

- It depends on the intrinsic permeability of the soil and on the degree of saturation.

- Saturated hydraulic conductivity, $K_{sat}$, describes water movement through saturated media.
• **Infiltration** is the process by which water on the ground surface enters the soil.
• **Infiltration rate** in is a measure of the rate at which soil is able to absorb rainfall or irrigation. It is measured millimeters per hour.
• The rate decreases as the soil becomes saturated.
• If the precipitation rate exceeds the infiltration rate, runoff will usually occur unless there is some physical barrier. It is related to the saturated hydraulic conductivity of the near-surface soil.
• The rate of infiltration can be measured using an infiltrometer.
Soil water

- One of the main functions of soil is to store moisture and supply it to plants between rainfalls or irrigations.
- If the water content becomes too low, plants become stressed. Soil water content is expressed on a gravimetric or volumetric basis.
- **Gravimetric water content** \( (\theta_g) \) is the mass of water per mass of dry soil.
- It is measured by weighing a soil sample (\( m_{\text{wet}} \)), drying the sample to remove the water, and then weighing the dried soil (\( m_{\text{dry}} \)).
• **Volumetric water content** (\(\theta_v\)) is the volume of liquid water per volume of soil. Volume is the ratio of mass to density (\(\rho\)) which gives:

\[
\theta_v = \frac{\text{volume}_{\text{water}}}{\text{volume}_{\text{soil}}} = \frac{m_{\text{water}}}{\rho_{\text{water}}} = \frac{m_{\text{soil}}}{\rho_{\text{soil}}} = \frac{\theta_g \times \rho_{\text{soil}}}{\rho_{\text{water}}}
\]
Measuring soil moisture

1. **Gravimetric method**
   - Take a moist sample, weigh, oven dry, weigh and determine % moisture.

2. **Tensiometers**
   - Measures soil moisture tensions. It measures the suction that the soil is exerting on the water.

3. **Electrical Resistance Method**
   - Two electrodes are imbedded in a block of gypsum. When placed in moist soil, the gypsum block becomes moist. A meter is used to measure electrical resistance between the electrodes. The greater the moisture, the greater the flow of current.
Forms of Soil Water

- **Chemical water** is an integral part of the molecular structure of soil minerals. It can be held tightly by electrostatic forces to the surfaces of clay crystals and other minerals and is unavailable to plants.

- **Gravitational water** is held in large soil pores and rapidly drains out under the action of gravity within a day or so after rain. Plants can only make use of gravitational water for a few days after rain.

- **Capillary water** is held in pores that are small enough to hold water against gravity, but not so tightly that roots cannot absorb it. This water occurs as a film around soil particles and in the pores between them and is the main source of plant moisture.
• When soil is saturated, all the pores are full of water, but after a day, all gravitational water drains out, leaving the soil at **field capacity**.

• Plants then draw water out of the capillary pores, readily at first and then with greater difficulty, until no more can be withdrawn and the only water left are in the micro-pores.

• The soil is then at **wilting point** and without water additions, plants may die.
Saturation
All pores are full of water. Gravitational water is lost

Field Capacity
Available water for plant growth

Wilting Point
No more water is available to plants
Water holding capacity (mm/cm depth of soil) of main texture groups. Figures are averages and vary with structure and organic matter differences.

<table>
<thead>
<tr>
<th>Texture</th>
<th>Field Capacity</th>
<th>Wilting point</th>
<th>Available water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse sand</td>
<td>0.6</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Fine sand</td>
<td>1.0</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td>Loamy sand</td>
<td>1.4</td>
<td>0.6</td>
<td>0.8</td>
</tr>
<tr>
<td>Sandy loam</td>
<td>2.0</td>
<td>0.8</td>
<td>1.2</td>
</tr>
<tr>
<td>Light sandy clay loam</td>
<td>2.3</td>
<td>1.0</td>
<td>1.3</td>
</tr>
<tr>
<td>Loam</td>
<td>2.7</td>
<td>1.2</td>
<td>1.5</td>
</tr>
<tr>
<td>Sandy clay loam</td>
<td>2.8</td>
<td>1.3</td>
<td>1.5</td>
</tr>
<tr>
<td>Clay loam</td>
<td>3.2</td>
<td>1.4</td>
<td>1.8</td>
</tr>
<tr>
<td>Clay</td>
<td>4.0</td>
<td>2.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Self-mulching clay</td>
<td>4.5</td>
<td>2.5</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Source: Department of Agriculture Bulletin 462, 1960
Water quality

• Soil quality is the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation.

• The most important issues related to water quality involve salinization and contamination of ground and surface waters by pesticides, nitrates and selenium.
Inherent and Dynamic Qualities of Soil

• Soil has both inherent and dynamic qualities.

• **Inherent soil quality** is a soil’s natural ability to function. For example, sandy soil drains faster than clayey soil.

• Deep soil has more room for roots than soils with bedrock near the surface. These characteristics do not change easily.

• **Dynamic soil quality** is how soil changes depending on how it is managed.

• Management choices affect the amount of soil organic matter, soil structure, soil depth, water and nutrient holding capacity.
Assessing Soil Quality

- Soil quality assessment is the process of measuring the management induced changes in soil.
- The ultimate purpose of assessing soil quality is to provide the information necessary to protect and improve long-term agricultural productivity, water quality, and habitats of all organisms including people.
- Soil quality cannot be measured directly, so we evaluate indicators.
- Indicators are measurable properties of soil or plants that provide clues about how well the soil can function.
- Indicators can be physical, chemical, and biological properties, processes, or characteristics of soils.
- They can also be morphological or visual features of plants. Useful indicators:
## Examples of soil quality indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Relationship to Soil Health</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil organic matter (SOM)</td>
<td>Soil fertility, structure, stability, nutrient retention; soil erosion</td>
</tr>
<tr>
<td>Physical: soil structure, depth of soil, infiltration and bulk density; water holding capacity</td>
<td>Retention and transport of water and nutrients; habitat for microbes; estimate of crop productivity potential; compaction, plow pan, water movement; porosity; workability</td>
</tr>
<tr>
<td>Chemical: pH; electrical conductivity; extractable N-P-K</td>
<td>Biological and chemical activity thresholds; plant and microbial activity thresholds; plant available nutrients and potential for N and P loss</td>
</tr>
<tr>
<td>Biological: microbial biomass C and N; potentially mineralizable N; soil respiration.</td>
<td>Microbial catalytic potential and repository for C and N; soil productivity and N supplying potential; microbial activity measure</td>
</tr>
</tbody>
</table>
Water conservation

• Water conservation can be defined in any of the following ways:

1. Any beneficial reduction in water loss, use or waste as well as the preservation of water quality.

2. A reduction in water use accomplished by implementation of water conservation or water efficiency measures; or,

3. Improved water management practices that reduce or enhance the beneficial use of water.
A successful water management program will use the following simple principles:

- **First Principle** – Conserve water whenever possible.

- **Second Principle** – Reuse water whenever possible.

- **Third Principle** – Know where and how water is used.

- **Fourth Principle** – Continually evaluate water use requirements.
Methods of Water Conservation

1. Conservation Tillage
   • Conservation tillage helps preserve soil moisture by leaving at least 30% of the soil surface covered with crop stubble, thereby decreasing wind and water erosion.
   
   • The crop stubble layer reduces evaporation in the soil profile by one-half compared to bare soil.
   
   • Conservation tillage can also reduce pollution caused by runoff and enrich the soil with organic matter.
2. **Mulch Tillage**

- Mulch tillage also called mulch farming is the practice of tilling a soil in a manner that most crop residues on the soil surface.

- The goal of mulch tillage is to control weeds and prepare a seedbed for the next crop, yet retain adequate residues on the surface to control erosion and improve water conservation.
3. Contour Tillage

- Contour tillage involves performing cultural operations such as plowing, planting and cultivating across the slope of the land so that elevations along rows are almost level.

- This system protects both the soil and water from losses associated with runoff.
4. **Furrow Diking**

- Furrow diking conserves water by capturing precipitation or irrigation water in small earthen dams in the furrows.

- Water held between the dams can slowly infiltrate into the soil, increasing soil moisture and reducing or eliminating runoff.

- Furrow dikes can benefit dry land farmers, sprinkler irrigators and furrow irrigators who water alternate rows.
5. **Drip Irrigation**

- Drip irrigation applies small amounts of water frequently to the soil area surrounding plant roots through flexible tubing with built-in or attached emitters.

- Subsurface drip irrigation (SDI) delivers water underground directly to roots. Since water is applied directly to individual plant roots, SDI minimizes or eliminates evaporation, provides a uniform application of water to all crop plants, and applies chemicals more efficiently.

- Irrigation also reduces plant stress and increases crop yield. A carefully managed amount of water is applied, thereby avoiding deep percolation and runoff, while reducing salt accumulation.
6. **Cover Cropping**

- Cover crops are close-growing crops such as legumes or grasses that are grown primarily to provide seasonal protection against erosion and for soil improvement.

- They usually main good soil moisture content.
7. **Land Leveling/Level Terraces**
   - Level bench terraces are widely used on steep slopes where land for crop production is limited and where precipitation is high.
   - On steep slopes, bench terraces separate the slope into a series of steps, with horizontal or nearly horizontal ledges separated from each other by vertical walls.
   - Level bench terraces have been used as a water conservation practice.

8. **Other Water Conservation Practices**
   - Recycling used water
   - Rain Water Harvesting
   - Chemical additives