Soil Water Overview

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Available water capacity and water holding characteristics of soils are critical to water management planning for irrigated and dryland crops. Deciding what crop to plant, plant population, when to irrigate, how much to irrigate, when to apply nitrogen, and how much nitrogen to apply depends, in part, on the water holding capacity of soils. Making prudent irrigation management decisions is critical to preserving the quantity and quality of Nebraska's water resources.

Soil Water Definitions

To adequately discuss soil water, you must be familiar with the following terms:

Soil water: water contained within or flowing through the soil profile. Surface water must infiltrate the soil profile to become soil water. Ground water is subsurface water in sufficient quantity that wells or springs can use it.

Excess soil water or gravitational water: water that drains or readily percolates below the active root zone by the force of gravity. Since drainage takes time, part of the excess water may be used by plants before it moves out of the root zone.

Available soil water: water that is retained in the soil and can be extracted by the plant. The **available soil water** is most important for crop production. It is the water held by the soil between **field capacity** and **permanent wilting point**.

Field capacity: the water content of a soil at the upper limit of the **available soil water** range. It is the amount of water remaining in a soil after the soil has been saturated and allowed to drain for approximately 24 hours.

Permanent wilting point: the lower limit of the **available soil water** range. When plants have removed all of the available water from a given soil, they wilt and will not recover. *Figure 3.1* illustrates the concepts of **field capacity** and **permanent wilting point**.

Minimum allowable balance: the soil water content at which crops begin to experience water stress. Plants can use approximately 50 percent of the available **soil** water without experiencing water *stress* (a shortage of water). Normally, the minimum allowable balance is 50 percent of the **available soil water**. For example, if your soil is a uniform loam with available soil water of 2.0 inches/foot, and the crop's active root zone is 3 feet, then the available soil water in the active root zone is 2.0 inches/foot times 3 feet or 6.0 inches. The **minimum allowable balance** in that three-foot active root zone would therefore be 6.0 inches times 50% or 3.0 inches.

Unavailable water: soil water held so firmly to soil particles by adsorptive soil forces that it cannot be extracted by plants. Unavailable water is still present when soil is drier than **permanent wilting point**.

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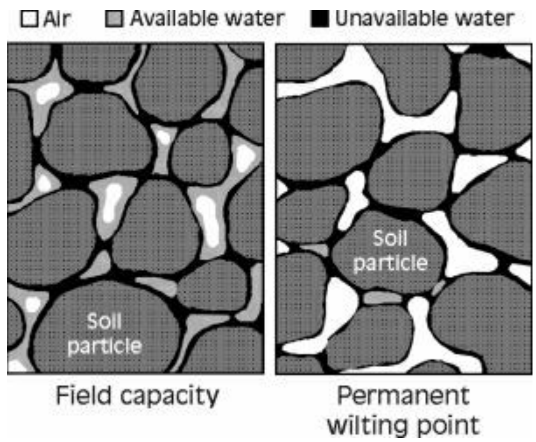

Figure 3.1. Illustration of field capacity and permanent wilting point.

Based on these definitions, soil water is classified into three categories: 1) excess soil water or gravitational water, 2) available soil water, and 3) unavailable soil water. Available water is further broken down into a) readily available water, no plant stress and b) less available water, plant stress likely. *Figure 3.2* is a schematic representation of soil water reservoir components. The size of the reservoir depends on the crop's active rooting depth.

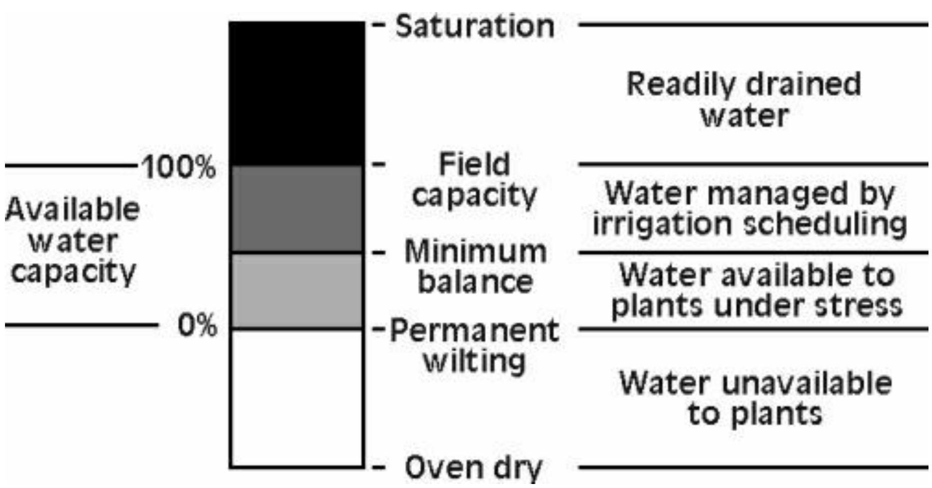

Figure 3.2. Components of the soil water reservoir.

__Soil Water Retention__

Despite the belief that soil absorbs water, water is actually "held" in the soil in two ways: 1) as a film coating on soil particles, and 2) in the pore space between particles, *Figure 3.1*. When water infiltrates into the soil from either precipitation or irrigation, the pore spaces are nearly filled with water. During and immediately after a rain or irrigation the greatest vertical movement of water occurs in the soil. After this initial movement, as the soil reaches **field capacity,** water movement continues due to gravity and capillary action. Capillary action is important for retaining water in the soil pores.

Small tubes (capillary tubes) can be used to illustrate capillary action. Like soil pores, capillary tubes come in different diameters. When one end of a capillary tube is placed in water, water will rise in the tube because the capillary action is stronger than the pull of gravity. Because capillary action is stronger than gravity, water will never completely drain through the soil profile. Some water will always be "held" in the soil profile.

Water rises farther in small capillary tubes than in larger ones. Larger capillary tubes correspond to coarser textured soils (sands have large pores). Smaller capillary tubes correspond to finer textured soils (clays have small pores). Capillary action can best be explained with an illustration, *Figure 3.3*.

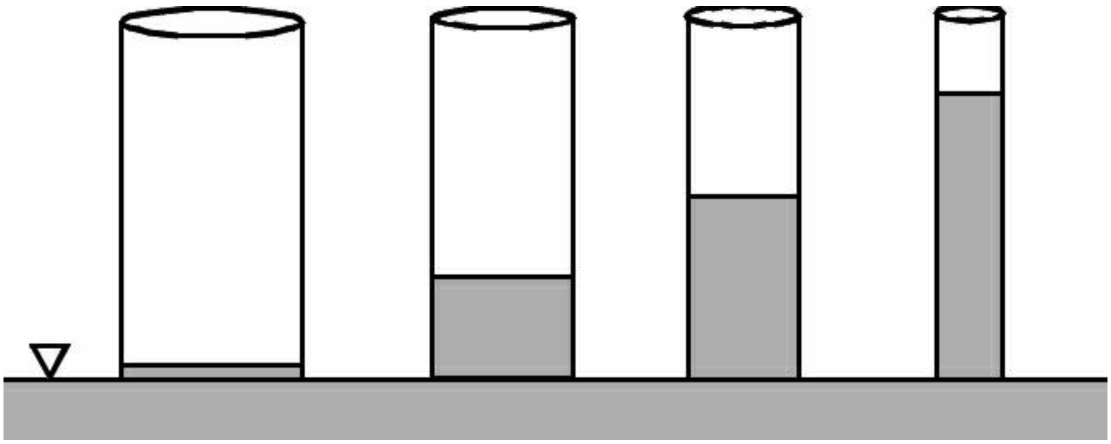

Figure 3.3. Capillary action is illustrated by how far water rises in tube of various diameters.

Figure 3.4 illustrates how water will be drawn up into four soil types. Four tubes containing soils of differing textures are placed upright in a tub of water. The water rises highest in the clay because it has the smallest pores. The clay soil exerts the greatest capillary action on the water. The fine sand having the larger pores exerts the least force.

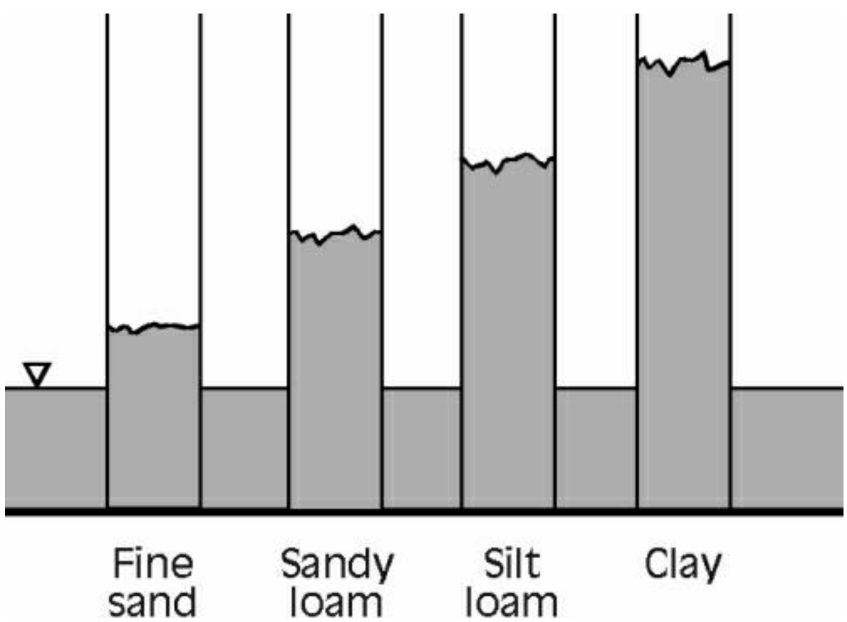

Figure 3.4. Capillary action illustrated by the relative height of wetting for four soil textures.

Figures 3.3 and *3.4* illustrate how water is held in soils. The capillary action or *tension,* which holds water in the soil, is most important to plant growth. Smaller pores hold water with more tension (negative pressure) than larger pores. As soil dries, the tension of the remaining water increases. Plants can extract less and less water as the soil water tension increases.

Available Water Capacities

A soil's water storage characteristics are very important for irrigation management. Since the size and number of pores in soils are directly related to soil texture, soil texture is the indicator for the amount of water a soil can hold. *Table 3.1* can be used to determine the amount of available soil water that a soil of a given texture will hold. This is its **available water capacity**. *Figure 3.5* shows the actual quantity of water stored for four soil textures. The numbers are presented on an inches per foot basis.

Table 3.1. Available water capacity based on soil texture.

Textural Classes	***Available water capacity in inches per foot of depth***
Coarse sand	0.25 - 0.75
Find sand	0.75 - 1.00
Loam sand	1.10 - 1.20
Sandy loam	1.25 - 1.40
Fine sandy loam	1.50 - 2.00
Silt loam	2.00 - 2.50
Silty clay loam	1.80 - 2.00
Silty clay	1.50 - 1.70
Clay	1.20 - 1.50

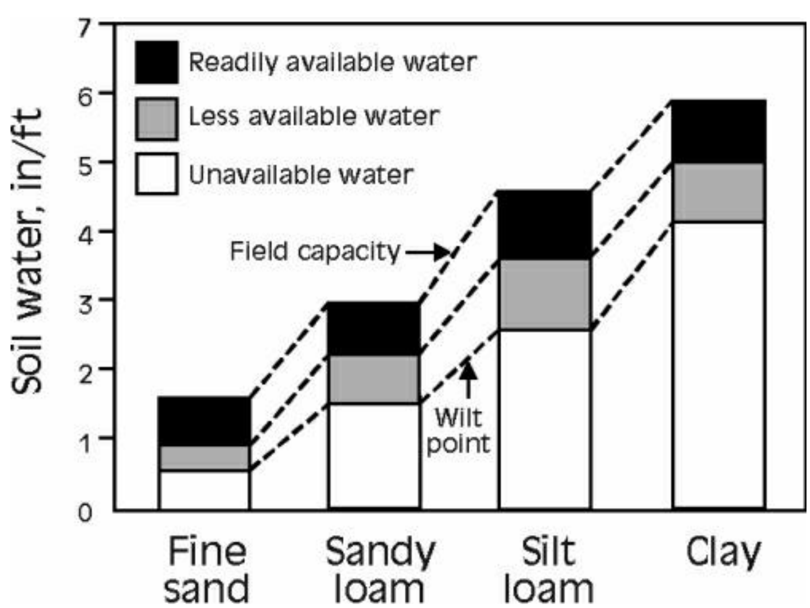

Figure 3.5. Soil water components in four common soil types.

Knowing the soil water content in the crop's active root zone and the available water capacity is key to applying the right amount of irrigation at the right time, i.e., irrigation scheduling. Soil water holding characteristics are important for irrigation system selection, irrigation scheduling, crop selection, and maintaining groundwater quality. Since soil can hold only so much water, excess or gravitational water moves out of the crop root zone toward the groundwater table. Many nutrients and chemicals move with the water and can eventually be found in the groundwater, thereby degrading the quality of this resource.

Infiltration

To this point we've discussed how and why the soil holds water, where soil water is retained, and how much water may be stored in a variety of soil types. With that background, let's turn our attention to how water moves into the soil profile. **Infiltration** is the process by which water enters into the soil. **Intake** or **infiltration rate** is the speed at which water can be taken into soil during an irrigation or rainfall event.

To see how infiltration changes, we'll look at the infiltration at the upper end of a row being furrow irrigated on a Hastings silt loam soil. *Figure 3.6* illustrates a typical infiltration curve for this soil. In this example, when water first enters the furrow, the **initial infiltration rate** at the top of the field is about 1.5 inches per hour. After two hours the intake rate has decreased to just under 0.5 inches per hour. This means that after four hours total infiltration is equal to 2.4 inches and the infiltration rate is close to the **basic infiltration rate** of 0.25 inches per hour. For a 12-hour irrigation, the total infiltration at this location is 4.6 inches, with a little over half that amount being infiltrated in the first four hours.

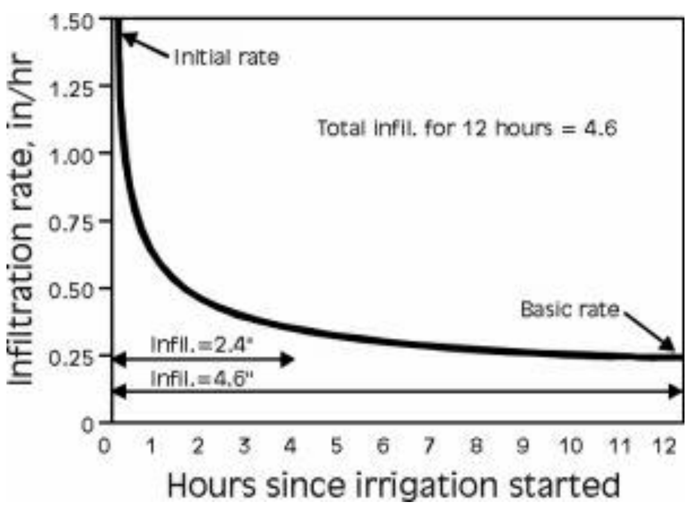

Figure 3.6. Typical infiltration curve for Hastings silt loam soil.

The Natural Resource Conservation Service groups soils into one of four intake families, based on the soil's basic infiltration rate (from greatest to least — A, B, C, D). The NRCS and county soil surveys can provide information relative to the soils in your area. This information and more is also available using the web soil survey at http://soils.usda.gov/. A range of basic infiltration rates for four common soil textures is presented in *Table 3.2.* Some typical generic infiltration curves for different soils are shown in *Figure 3.7*. For a sandy soil both the initial and basic infiltration rate are usually greater than that for a silt loam. The basic infiltration rate for a very sandy soil may be almost as great as the initial rate for a very fine textured soil.

Table 3.2. Range of infiltration rates for several soil textures.	
Soil texture	***Basic infiltration rate, in/hr***
Fine sand	0.50 - 0.75
Sandy loam	0.35 - 0.50
Silt loam	0.25 - 0.40
Clay	0.10 - 0.20

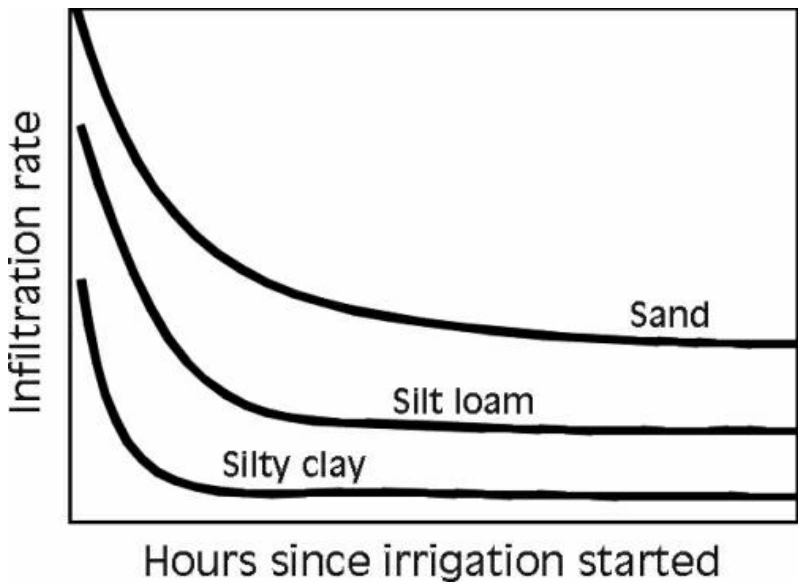

Figure 3.7. Typical infiltration curves for different soil textures.

Infiltration rates change over the growing season. At any given time, they will likely vary across a field, even though the soil "appears" uniform. Soil surface conditions (wet or dry, cloddy or smooth, cracked or solid, compacted or loose) also affect infiltration. Plant residue left on the soil surface acts to disperse the energy of rain and sprinkler droplets. Reducing the energy of these droplets reduces compaction from the force of the droplets and inhibits soil surface crusting that sometimes occurs. Partially incorporating crop residues can enhance infiltration by providing avenues of water entry into the soil. Tillage may or may not increase infiltration. Deep tillage, like that performed with a chisel, generally increases infiltration rates by increasing surface roughness which increases the opportunity for water to move into the soil. While proper tillage can increase infiltration rates, excessive or improper tillage can cause compaction at or near the soil surface. Compaction decreases infiltration rates. Soil slope also affects infiltration. Water applied to a steeper sloping field will obviously have less opportunity to infiltrate and more opportunity to run off.

<u>Water Movement in Soil</u>

How water moves once in the soil is an important factor in determining the suitability of land for irrigation. Movement or **redistribution** of water in the soil is dependent upon the size, number and continuity of the soil pores.

Water movement through fine-textured soil into underlying sand and gravel does not occur until the finer material above the gravel is fully saturated *(Figure 3.8a)*. Because the smaller pores, in the finer material in the upper layer, have a greater attraction for the water than the relatively larger pores on the underlying layer, the water moves laterally and fills the upper layer before moving into the coarse material below. Remember, the fine textured soil was able to move water higher in the soil column. After the upper layer becomes saturated, water enters the underlying layer *(Figure 3.8b)*. The practical implication of this demonstration is that in shallow soils underlain by sands, like those found in the Platte River Valley, water movement is actually slowed by the underlying coarse sand and gravel layer.

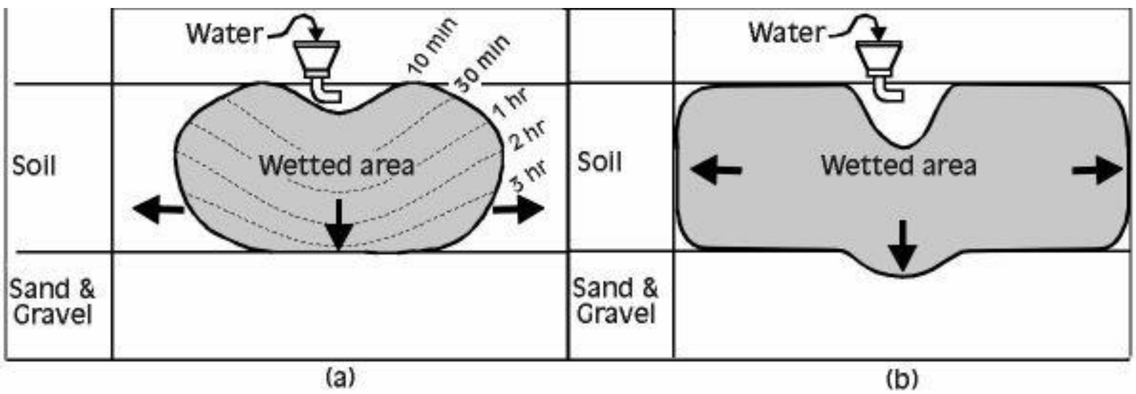

Figure 3.8. Water infiltrating into soil underlain by coarse sand and gravel.

What happens to water movement if the upper soil layer is underlain by a finer textured material like clay? As *Figure 3.9a* illustrates, water moves rapidly into the clay. Compared to the overlying layer, the smaller pores associated with clay layer have a greater attraction on the water. This causes the clay to wet immediately when the wetting front reaches the layer. Although the clay layer wets rapidly, the small pores hold the water tightly and effectively retard the advance of the wetting front. The slowing of the wetting front causes lateral water movement in the overlying coarse soil. Finally, after the clay layer is saturated, the wetting front will move below the clay, *Figure 3.9b*. The situation illustrated in *Figure 3.9* is typical of soils with buried claypans. The claypan restricts the downward (or upward) movement of water. If a claypan is at or near the soil surface, excessive runoff may become a problem during rainfall or irrigation events even though the soil below the clay pan is dry. A subsurface clay layer also can cause the soil above it to become fully saturated forming a **perched water table**. Perched water tables often cause drainage and aeration problems in the upper soil layers.

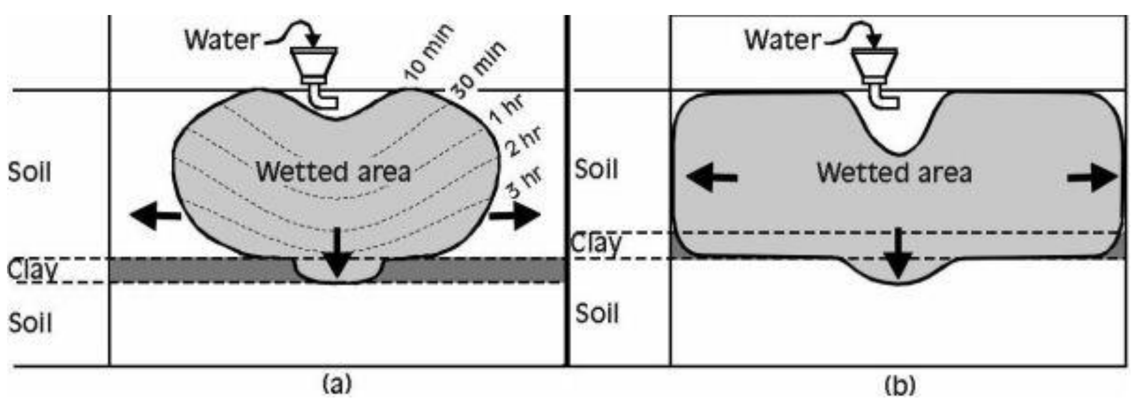

Figure 3.9. Water infiltrating into soil underlain by clay layer.