Soil-Water Management[1]

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PHYSICAL CONCEPTS RELATED TO SOIL-WATER MANAGEMENT

The movement and retention of water in soils are controlled primarily by physical properties of soils. Soil structure is defined as the physical constitution of a soil material as expressed by size, shape and arrangement of the soil particles and associated voids. Soil particles include mineral and organic material as primary and secondary or aggregate units. The size distribution of these particles influences the size distribution of pores and the total pore space (see I-7.3). Porosity (P) of soil can be calculated as:

$$P = \frac{(1 - BD) \ x \ 100}{PD}$$

where BD is the bulk density (the dry mass of the natural, undisturbed soil per unit volume) and PD is the particle density (mass per unit volume of the solid particles without voids) (See Soil Science Fact Sheet, SL-37). Porosity is expressed as a volume percent.

Water is held within the void space by adhesive and cohesive forces. The water molecules adhere (adhesive force) to soil particle surfaces and are attracted to other water molecules by cohesive forces. These forces control the wetting of soils by water and the continuity of water in the soil pores. A soil is considered saturated when all the pore spaces are filled with water. (See Soil Science Fact Sheets, SL-37 & SL-38).

WATER HOLDING CAPACITY

Due to the void spaces in soils, there exists a capacity to store water for use by plants. During and immediately following rainfall or irrigation the soil pores are filled with water. With time, gravity drainage results in a decrease in soil-water content. The initial rapid drainage leads to a condition described as "field capacity." Although widely used, "field capacity" is not easily defined since it depends not only on the soil texture and structure but also on the drainage characteristic of the soil profile.

Field capacity has been defined as the water content at which the initial rapid gravity drainage ceases or becomes negligible. For fine textured soils this may take several days, however, for coarse textured soils (sands) the condition occurs in one day or less. Field capacity can be measured only in the field. However, it is often estimated for well-drained soils from laboratory measurements on disturbed soil samples: 1/10-bar water content for sandy soil, and 1/3-bar water content for medium- or fine-textured soils.

Plants extract water from the soil to meet physiological needs. As the soil dries out plants must expend more energy to take up sufficient water for their needs. As a plant's demand for water exceed the soil's capacity to provide the water, the plant will show symptoms of wilt. The soil water will eventually be depleted to the point that the wilted plants will not recover. This condition is called the "permanent wilting point" or "permanent wilting percentage" (PWP) and is expressed as the water content of the soil at which that condition occurs. From laboratory studies the water content at PWP has been found to

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be essentially equivalent to the water content at 15 bars soil moisture tension.

Since gravity drainage to field capacity occurs relatively rapidly, water available to plants is generally considered to be that between field capacity and PWP. This property is called "Available Water Capacity" (AWC). AWC can be calculated as follows:

$$AWC = T \times \frac{(FC - PWP) \times BD}{DW \times 100}$$

where:

AWC = Available Water Capacity in cm
BD = Bulk density (gms/cm)
T = Thickness of root zone in cm
FC = Field Capacity (% by weight)
PWP = Permanent Wilting Percentage (% by weight)
DW = Density of Water (gms/cm)

Thus AWC is expressed in cm of water in the root zone of thickness - T cm.

Figure 1 provides an example of the relationships between FC, PWP, and AWC for soils of three textures. Note that the AWC is much greater for the silt loam than for the sandy loam. This difference is primarily due to the differences in water content at field capacity. Sands have very low AWC. Table 1 gives typical AWC data for selected Florida soils.

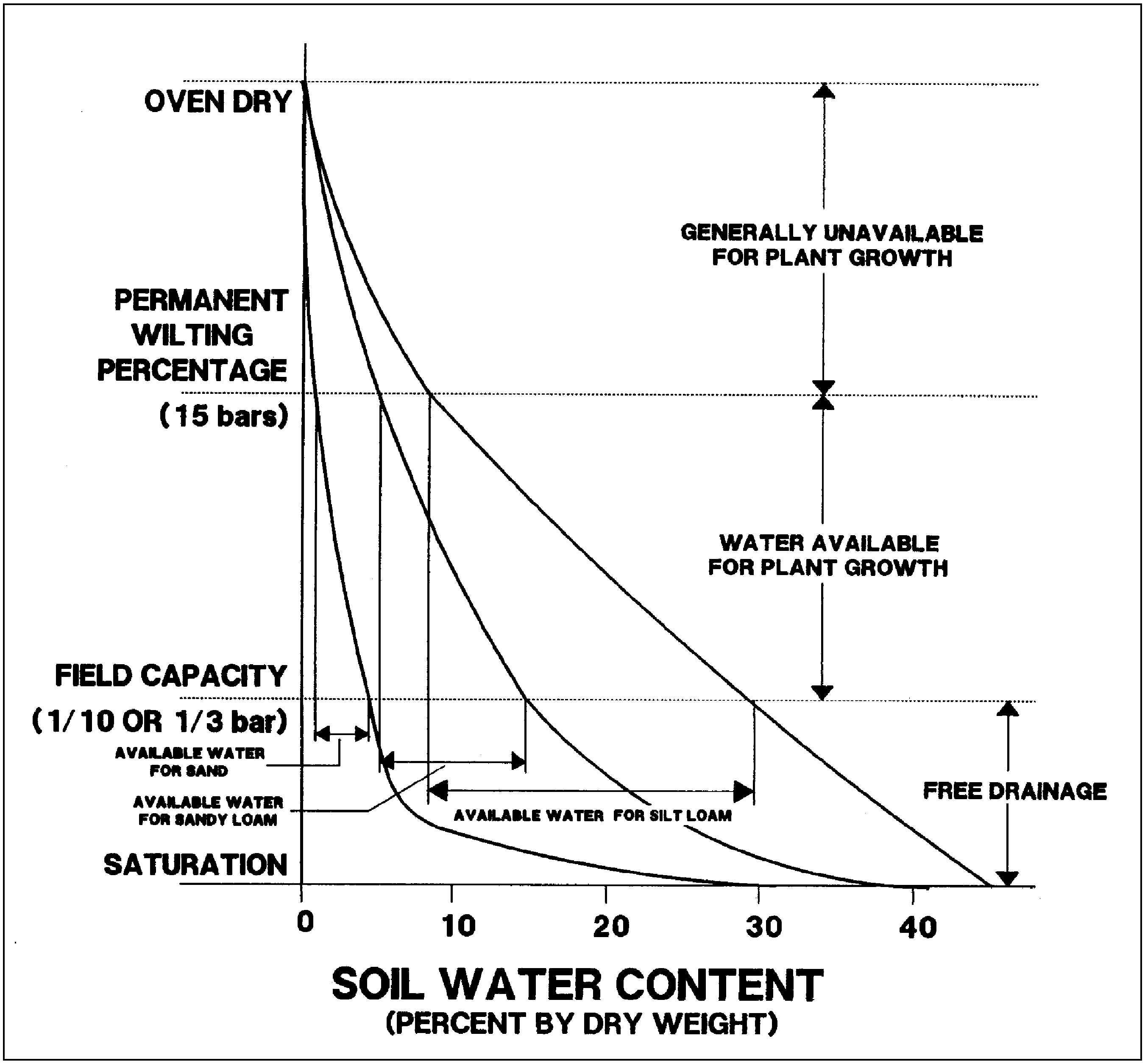
Note: The concepts of field capacity and available water capacity hold for well drained and moderately well drained soils. However, for poorly drained soils care should be used in interpreting these parameters.

Table 1. Classification and Soil-Water Properties of Selected Florida Soils

Soil Series Classification	Natural Drainage	Available Water Capacity (inches) 0-6"	6-12"	12-24"	Hydraulic Conduc-tivity* (in./hr.)
Lakeland sand (Typic Quartzipsamment)	Excessive	0.39	0.38	0.74	24.2
Paola sand (spodic Quartzipsamment)	Excessive	0.14	0.08	0.21	36.0
Gainesville sand (Typic Quartzipsamment)	Good	0.65	0.57	0.90	8.3
Orangeburg fine sandy loam (Typic Paleudult)	Good	0.73	0.91	2.13	1.4
Tavares fine sand (Typic Quartzipsamment)	Moderately good	0.39	0.27	0.43	8.2
Goldsboro sand (Aquic Paleudult)	Moderately good	0.42	0.42	1.38	0.2
Electra fine sand (Arenic Ultic Haplohumod)	Somewhat poor	0.32	0.22	0.41	<0.1
Sparr fine sand (Rossarenic Paleudult)	Somewhat poor	0.67	0.65	1.20	<0.1
Myakka fine sand (Aeric Haplaquod)	Poor	0.68	0.54	0.47	3.6
Bladen sand (Typic Albaquult)	Poor	0.72	0.72	1.34	<0.1
Placid loamy sand (Typic Humaquept)	Very poor	2.09	1.69	1.03	7.0
Lauderhill muck (Lithic Medisaprist)	Very poor	2.41	2.42	5.77	24.6

* Least permeable horizon within pedon depth (80 in.). (From Carlisle and Hallmark, 1977)

Figure 1. Relationships between Field Capacity, Permanent Wilting Percentage, and Available Water Capacity for three soil textural classes.



MEASUREMENT OF SOIL WATER CONTENT

Soil-water content can be measured by direct and indirect methods. The most common and least expensive is the gravimetric method. This method consist of weighing out approximately 20 grams of moist soil, drying it in an oven at 105 degrees C until there is no weight change then weighing for the final over dry weight. The gravimetric water content (WCg) is then determined as follows:

$$WCg = \frac{MoistWeight - OvenDryWeight \times 100}{OvenDryWeight}$$

and is expressed as a weight percent. Sometimes it is convenient to express the water content on a volume basis (WCv). This requires knowledge of the bulk density of the soil when the sample was taken. The relationship between WCg and WCv is as follows:

$$WCv = \frac{WCg \times BD}{DW}$$

where WCv is expressed as a volume percent. It is important to note that one must know whether water-content data are expressed on a volumetric basis or on a gravimetric basis since they are different and could lead to serious errors if used interchangeably.

Indirect methods of soil-water content measurement include neutron scattering, gamma-ray attenuation, and tensiometry (see Smajstrla and Harrison, 1982). The nuclear methods require expensive electronic instrumentation and a license to use the radioactive source. The use of tensiometers requires a laboratory determined water-release curve to translate from soil-water tension values to water contents on a volume basis (See Soil Science Fact Sheet, SL-38).

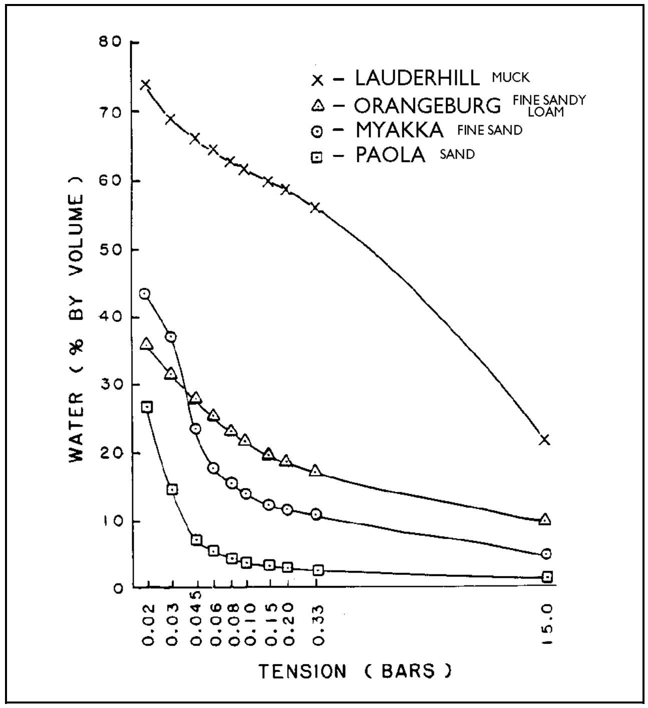
For most applications the direct gravimetric method is sufficient and the least expensive. (See Florida Irrigation Guide, USDA-SCS, 1982 Chapter II and Appendix A).

SOIL-WATER POTENTIAL AND MOVEMENT

Water moves in soils in response to potential (energy) gradients. These energy gradients arise from several causes such as gravitional forces, capillary forces, and osmotic forces. Such energy gradients can be expressed as pressure per unit area (positive or negative). In soils the soil-water potential is expressed as a negative pressure head, as a "suction", or as a "tension" and can be expressed in terms of pressure (millibars, bars, psi, etc.) or in terms of equivalent depth of water (inches or centimeters of water). [One bar pressure 1034 cm equivalent water height 14.7 pounds per square inch (psi).]

The water content of a soil at a given time is related to the pressure head which is acting upon that soil. The water content at a given pressure head differs with soils of different textures due to differences in capillary forces. The finer the texture of the soil the smaller the pores resulting in greater capillary forces. This results in a higher water contents in finer textured soils than coarser textured soils at the same pressure head. Figure 2 depicts this relationship for some Florida soils. (See Soil Science Fact Sheet, SL-38 and Carlisle and Hallmark, 1977).

Figure 2. Water retention at selected tensions for surface horizons for four Florida soils.



Tensiometers measure the pressure head of water in soil. Since the ability of plants to remove water from soils is related to the soil-water pressure, the tensiometer is placed in the soil at a depth relevant to the rooting pattern of the crop being grown and is used to measure depletion of moisture. The amount of depletion allowed will depend on the soil, the crop being grown and the irrigation system.

Movement of water in soil is important for drainage, crop uptake, and nutrient and pesticide leaching. Overirrigation can lead to leaching of fertilizers (especially nitrogen and potassium) to depths below the active root zone, thereby effectively removing the nutrients from access by the crop. Likewise soil-applied pesticides may be leached if they are fairly water soluble and have low sorption values (See Soil Science Fact Sheet SL-40. For these reasons knowledge of water movement is important not only for crop production, but also for environmental and public health considerations.

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