B-1330 • September 2018

IRRIGATION MANAGEMENT: BASICS OF SOIL WATER

Vivek Sharma
Extension Irrigation Specialist
Department of Plant Sciences
University of Wyoming

This bulletin presents and discusses the fundamental concept of soil water relationships for efficient irrigation scheduling. Understanding soil water relationships assists in decision-making in agriculture and natural resources management. In addition, better understanding of definitions and terms associated with soil water can aid communication between agricultural producers, irrigation practitioners, extension personnel, researchers, and water management and regulatory agency personnel.

SOIL COMPOSITION

Soil has four major components: mineral, air, water, and organic matter content (Figure 1). The mineral solid fraction of the soil is made up of sand (large particles), silt (medium particles) and clay (fine particles). Nearly all soils have a mixture of these particles. **Soil texture** is the relative proportion of each of these fractions in soil.

Clay is the smallest particle size, and clay soils tend to hold water and nutrients well and drain poorly. Conversely, soils containing a large proportion of sand tend to drain well and do not hold water and nutrients well. The equivalent diameter size limits are clay < 0.0000079 inch, silt 0.0000079 to 0.00079 inch, and sand 0.00079 to 0.079 inch. Particles larger than 0.079 inch are referred to as rock fragments and not used in determining soil texture, although they can influence soil structure and soil water relationships. Many soil properties are influenced by soil texture, including **percolation, water-holding capacity, aeration, susceptibility to erosion, cation exchange capacity,** and **soil tilth**.

The relative proportions of the mineral fractions of major soil types in northwest (NW) and southeast (SE) Wyoming agricultural regions at 1-foot and 2 feet depths is illustrated in Figure 2. The NW region contains the soils of Bighorn, Park, and Washakie counties, and the SE region contains the soils of Goshen, Laramie, and Platte counties. Greater variation in soil types was observed in the NW region where soils are a little heavier (i.e., higher percentage of clay) than in the SE. In the NW, soil types vary from loam to sandy clay loam to sandy loam compared to the SW region where soils are generally categorized between loam and sandy loam.

The water and air fractions are contained in the open space, (also called **voids** or **soil pores**) between soil particles (Figure 2). The proportion of water and air fraction varies by soil type and time. For example, after a large rainfall event, the pore space occupied by water will increase and the air-filled pore space will decrease. However, during prolonged dry periods, the air-filled pore space will increase due to **soil evaporation** and **plant transpiration** (commonly known as **crop evapotranspiration or ETc**) and percolation of water from the root zone. Detailed information of ETc is provided in the UW Extension Bulletin "*Evapotranspiration: Basics, Terminology and its Importance, B-1293.*"

Porosity is the measure of relative pore space that indicates the amount of open space between the soil particles. The size of a pore in a soil affects how the pore functions and amount of water it can hold. The larger macropores (pore size larger than 0.003 inch) allow rapid movement of water and air in contrast to micropores (pore size less than 0.003 inch) that retain water and cause the slow movement of water and air. Coarse-textured soils have relatively large particles that do not pack together tightly. Consequently, the movement of air and water is rapid. For many soils, the porosity ranges approximately from 30 to 60 percent of the total soil volume.

Although fine-textured soils have more pore space than coarse-textured soils, the individual pore sizes are much smaller than those in soils with a high sand content. Clay soils hold more water than coarse-textured soils, but because of the large surface area of the clay particles, much of this water is held strongly by the soil particles, making it difficult for plant roots to extract the strongly bound water molecules. However, increasing organic matter content in fine-textured soil helps in increasing porosity, promotes root penetration, and earthworm movements and can improve soil water **infiltration** and movement. Medium-textured soils, with high organic matter content and little compaction, have a high total porosity due to the increase in **capillary** pores. Capillarity is defined as the upward movement of water in small pores against gravity, due to the attraction of water to the solid surface and the surface tension of water.

Infiltration is the process by which the reservoir of water in soil is replenished by entry of water through the soil surface. It can be described in terms of either the rate of infiltration, which is the depth of water that infiltrates per unit of time, or the cumulative amount of water that infiltrates over time.

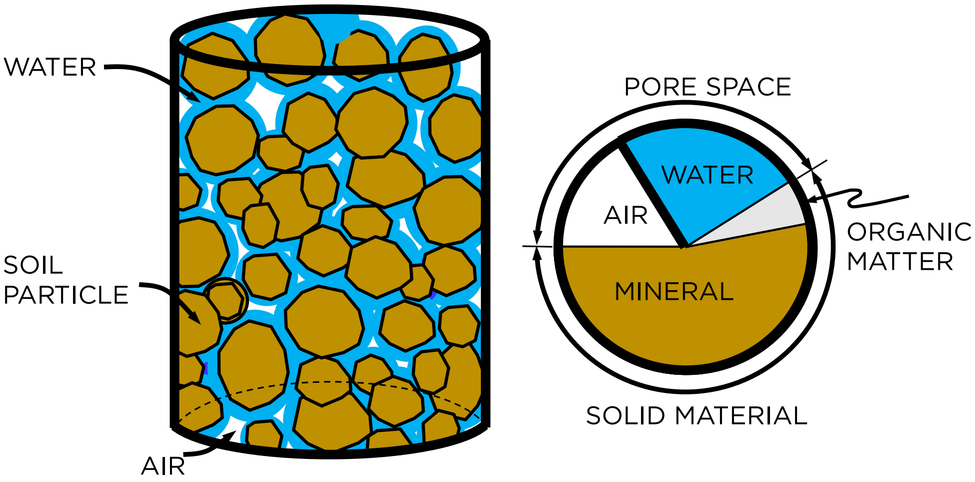


Figure 1. *The composition of unsaturated soil volume illustrating components of soil (water, air, organic matter, and minerals).*

Infiltration is a very important soil property in irrigation since the goal of irrigation is to provide water to the root zone to meet crop water needs. Capillarity and gravity are the two main drivers that cause the movement of water in the soil profile. Capillary forces dominate water movement in the soil during the beginning of irrigation. Capillary forces pull water into the soil in horizontal and vertical directions. Capillary forces diminish and gravity becomes the dominant factor as time progresses.

The infiltration rate is much higher at the beginning of an irrigation or rainfall event and decreases gradually as the soil gets wetter. The rate at which the infiltration rate decreases is very important for effective irrigation management because the infiltration rate and amount of water change from the beginning to the end of water application. For example, the infiltration rate is higher when the entire soil surface is wet compared to only a portion of the surface. The infiltration rate is generally higher for border and basin irrigation than for furrow irrigation where only a portion of the soil surface is in contact with water. In general, the infiltration rate is highest for dry, coarse-textured soils and lowest for wet fine to medium textured soils.

Other factors that affect the rate of infiltration in the soil include method of irrigation, management practices, and soil crusting. Management practices such as conservation tillage that retain crop residue on the soil surface (such as no-till) enhance infiltration. In addition, crop residue on the soil surface protects the soil from the impact of water drops from sprinkler irrigation or rainfall and reduces the formation of a surface seal (Irmak and Djaman, 2015).

SOIL BULK DENSITY

Soil bulk density is the ratio of the mass of the dry soil to the total volume occupied by the soil, including the volume of the pores and expressed as:

$$\text{Bulk density} = \frac{\text{Mass of dry soil}}{\text{Total volume of soil}}$$

Bulk density is generally used as an indicator of soil porosity and soil compaction. Bulk density typically increases with soil depth since subsurface layers have less organic matter, aggregation, and root penetration compared to surface layers and contains less pore space. For example, within a soil of similar soil texture, a compacted soil has lower porosity and thus greater bulk density compared to loose soil. Soils with lower bulk density, such as sands, can promote vertical leaching of nutrients and reduce their availability to crops.

Bulk density can be substantially affected by soil management practices (including irrigation and tillage), within-field traffic (compaction), and organic matter content (Hillel, 1998). Decreases in organic matter content usually result in increased bulk density in agricultural soils.

For many agricultural soils, bulk density varies between 90.52 lb/ft^3 (1.45 g/cm^3) or greater for sandy soils; 87.4 to 90.52 lb/ft^3 (1.40 to 1.45 g/cm^3) for sandy loam

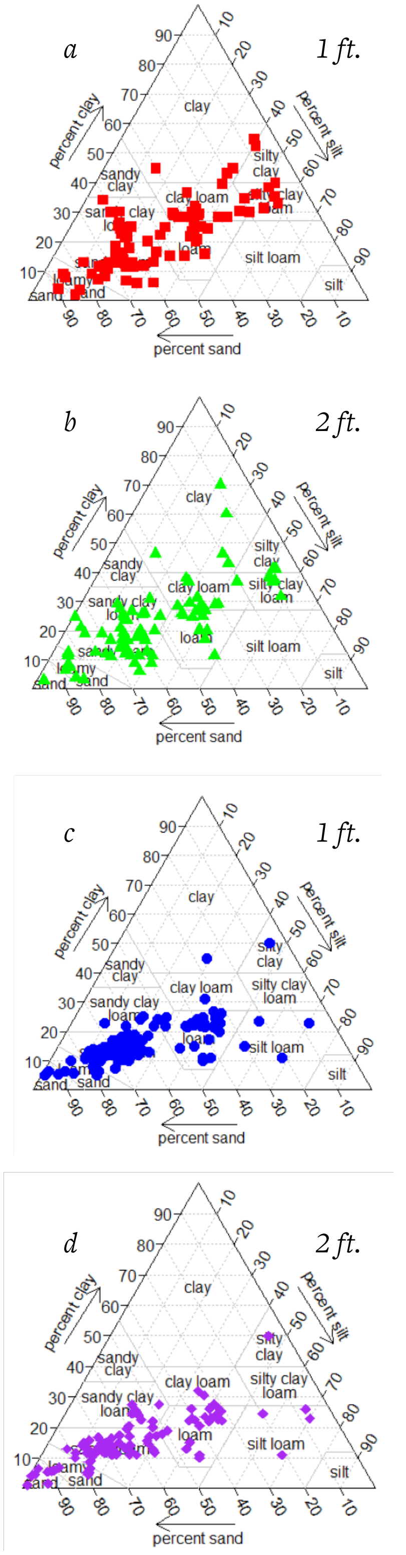


Figure 2. *The relative proportion of soil particle content (sand, silt, and clay content) for major soil types in the agricultural regions of northwest (a and b) and southeast (c and d) Wyoming at 1-foot and 2 feet depths. (Data source: USDA-NRCS web-soil survey https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx).*

soils; 86.04 to 87.4 lb/ft^3 (1.38 to 1.40 g/cm^3) for loam soils, 77.93 to 84.16 lb/ft^3 (1.25 to 1.35 g/cm^3) for silt loam soils, 68.57 to 74.81 lb/ft^3 (1.10 to 1.20 g/cm^3) for clay soils.

SOIL WATER CONCEPT

Equipped with an adequate understanding of soil water concepts, the irrigator will know how much and when to apply irrigation. The goal of irrigation management is to satisfy the plant's water requirement by maintaining the amount of water in the soil profile. When soil is too wet, the plant suffers inadequate aeration. When soil is too dry, plant roots have difficulty extracting the water they need from the soil. Determining the amount of soil water available to plant roots is necessary.

There are two measures of soil water which are important for managing irrigation. The first is the amount of water present in the soil, or **soil water content**. The second measure is **soil water potential**, which estimates the availability of water to plants. It is direct indication of the energy required by plant roots to obtain water from the soil. Before considering these two measures, understanding some basic terms, definitions, and concepts that will help make irrigation management choices is important.

Soil Water Content

The amount (volume) of water held in a unit volume of soil at any given time is the soil water content. Soil water content can be expressed as a percentage of dry soil weight (mass water content), percentage of soil volume (volumetric water content), a fraction of available water remaining, and a fraction of the available water depleted. It influences plant growth, soil temperature, transport of chemicals and groundwater recharge.

Mass water content or gravimetric water content is defined as the ratio of the mass of water per unit mass of dry soil mass. It is expressed as either a decimal fraction or as a percentage:

$$\text{Mass water content} = \frac{\text{Weight of wet soil - Weight of dry soil}}{\text{Weight of dry soil}}$$

For irrigation purposes, the common practice is to express the soil water content on a volumetric basis, which is defined as the ratio of the soil water volume to the total volume of undisturbed soil:

$$\text{Volumetric water content} = \frac{\text{Volume of water}}{\text{Total volume of soil}}$$

Since measuring the volume of water of an undisturbed soil sample is difficult, mass water content and soil bulk density are generally used to find the volumetric water content:

$$\text{Volumetric water content} = \frac{\text{Bulk density of soil}}{\text{Bulk density of water}} \times \text{Mass water content}$$

Volumetric water content can be expressed as a ratio, percentage, or depth of water per depth of soil such as inches of water per foot of soil. However, for practical application, it is often more convenient to express the soil water content in equivalent depths of water than as a percentage or ratio of water content:

Depth of water in a soil layer = Volumetric water content × Depth of soil layer

For example, if the volume of water is 25 percent of the volume of soil containing it, volumetric water content can be expressed 3.0 inches of water per foot of soil (0.25 × 12 inches of soil = 3.0 inches of water).

Soil Matric Potential

Soil water content can also be expressed as **soil water potential**, which is a measure of the energy status of soil water relative to that of water at a standard reference, and is generally expressed in units of pressure. Common units of pressure and their equivalents are shown in Table 1. The standard reference is generally denoted at a high energy level and assigned a value of zero; soil matric potential generally has negative values.

Table 1. Common units of pressure and their equivalents

Unit	Pressure equivalent
1 Atmosphere	101.3 kPa (kilopascal) 1.013 bar 101.3 cbar (centibar) 14.7 psi (lb/in^2)
1 psi (lb/in^2)	6.89 kPa

Soil matric potential indicates the ability and amount of energy that must be exerted by the plant to extract water from the soil profile. As the matric potential decreases (more negative value), the availability of soil water to a plant decreases and plants need to exert more energy to uptake soil water. For example, for wet soil, the soil matric potential has a small negative value (-0.4 bar or -40 kPa), and as values decrease (toward larger negative value; -15 bar or -1500 kPa), the availability of soil water to plants decreases and, thus, the plant roots have more difficulty taking up water as soil water content decreases. Since the availability of soil water to crop varies with soil texture, the amount of available water in the soil at the same matric potential value varies. For example, as the sand content in the soil increase, the amount of water retained at a given matric potential decreases. Figure 3 represents the soil water content at 100 kPa matric potential for silty clay loam soil (which has approximately 40 percent sand content) is about 30 percent (by volume), whereas, it is only 7 percent (by volume) for loamy sand, which has 80-90 percent sand content.

SOIL MOISTURE CHARACTERISTIC CURVE

Many soil moisture sensors provide soil moisture data in volumetric water content; however, few sensors report soil matric potential. To easily interpret the soil moisture available in the soil profile requires converting the soil matric values to volumetric water content. The relationship between volumetric soil water content and soil matric potential is generally described by **soil moisture characteristic curves** or **soil water retention curves**. Figure 3 illustrates the soil moisture characteristic curve for four major soil types in Wyoming (silty clay loam, loam, sandy loam, and loamy sand). Soil moisture characteristic curves are often used to define the amount of water available to plants. Most of the changes in volumetric water content occur at soil matric potential values of zero to 300 kPa (Figure 3). Beyond 300 kPa, the soil becomes too dry for plant root uptake.

Understanding soil water thresholds in irrigation scheduling is important to interpreting the soil water content. These thresholds are specific values of soil water content indicating soil water availability for crop uptake. Figure 4 illustrates the soil reservoir and associated terms. Remember that not all soil water is accessible to plants.

Saturation is when all soil pores are filled with water after a rain event or irrigation application. At this point, water is held at zero tension and will flow freely in response to gravity. Under natural conditions, the saturation point may not be reached due to trapped air bubbles; the term near saturation may be more descriptive.

Crops need air and water in appropriate amounts in the soil for a healthy crop-soil environment. At saturation, there is very little air present in the soil, and this affects the plant growth adversely. Many crops cannot withstand saturated soil conditions for a period of more than two to five days. Depending on soil type, the saturation point can vary from 40 percent (5.16 in/ft) for coarse-textured soil (sand) to 50-56 percent (6.68 in/ft) for fine-textured soil (clay). Figure 5 presents the amount of water at saturation for different soil types.

The water available to support plant growth is called **available water capacity** (**AWC**). AWC is the soil water content held between **field capacity** (**FC**) and **permanent wilting point** (**PWP**) (Figures 4 and 5). FC is the amount of soil water remaining in the soil profile after excess water due to a heavy rain event or irrigation application has drained away, and the rate of downward movement has decreased or stabilized. This usually is two to three days after rain or an irrigation application in pervious soils of uniform structure and texture. It is also considered to be the upper limit of plant available water (Figure 5). In terms of soil matric potential, it is the volumetric water content held at -0.1 bar for coarse-textured soil and -0.33 bar for fine-textured soil.

For any given soil, FC is a function of soil particle size distribution. For example, for most agricultural soils, FC ranges from 7-10 percent (0.9 to 1 in/ft) for coarse-textured soil to 45-50 percent (5.4 to 6 in/ft) for fine-textured soil. One way to effectively determine the FC is to measure soil moisture two, three, four, and five days after a rain or irrigation event and determine when the change in soil moisture is negligible.

The water that exists between saturation and FC is called **gravitational water** (Figure 4). It moves rapidly in the soil profile under the influence of gravity and is generally not available for crop uptake.

Permanent Wilting Point (**PWP**) is the soil water content at which the soil cannot supply water at a sufficient rate to maintain the turgidity of the plants, and the plants permanently wilt. At this point, the crop suffers from physiological and biophysical damage and plants cannot recover even if the soil water deficit is replenished by rain or supplemental irrigation.

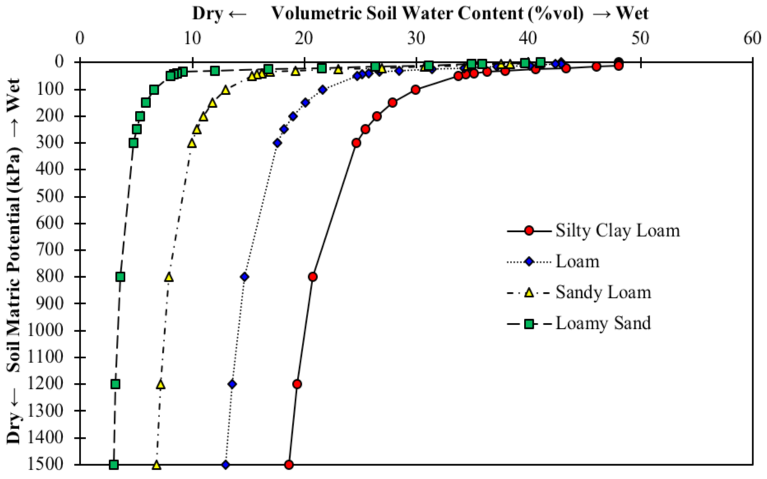


Figure 3. *Soil water release curves (soil characteristic curve) for four major soil types in Wyoming (silty clay loam, loam, sandy loam, and loamy sand). Curves were developed by a methodology developed by Saxton and Rawls, (2006).*

In terms of soil matric potential, PWP is the volumetric water content at -15 bar. At this tension, plants are generally unable to overcome the adhesive forces at which the soil matrix holds water. Similar to FC, PWP is also a function of soil particle size distribution. For example, for most agricultural soils, PWP ranges from 3-5 percent (0.4 to 0.6 in/ft) for coarse to medium-textured soil, to 35-40 percent (4.2 to 4.8 in/ft) for fine-textured soil.

Values of AWC, FC, and PWP vary substantially between soil types (Figure 5). These values are generally expressed in the units of the depth of the available water per unit depth of soil, for example, in/in or cm/cm. Depending on the soil type, there can be very different saturation, gravitational, AWC, FC and PWP (Figure 5). For example, sand for which significant portion is gravitational water and hold small amount of water for plant water uptake, as a result crop grown on sandy soils are more vulnerable to drought and require regular irrigation. On the other hand, for clay soils, most of the water stays in the soil profile due to enhanced aggregation; however, a majority of soil water in clay soils is unavailable to plant water uptake, as soil water is held very tightly in the micro pores plants cannot access. In many cases, loam to silt loam soils have higher AWC and are widely used for crop production. For example, for loam soil (common in Wyoming), volumetric water content at FC (Θ_{FC}) is 3.20 in/ft (27 percent by volume) and PWP (Θ_{PWP}) is 1.56 in/ft (13 percent by volume) (Figure 4). Thus, the AWC is 1.64 in/ft (3.20 in/ft – 1.56 in/ft) (14 percent by volume).

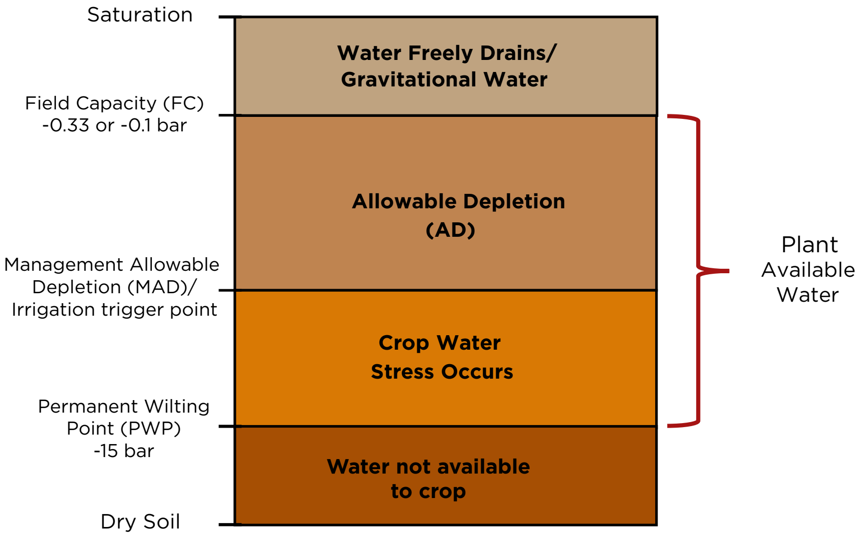
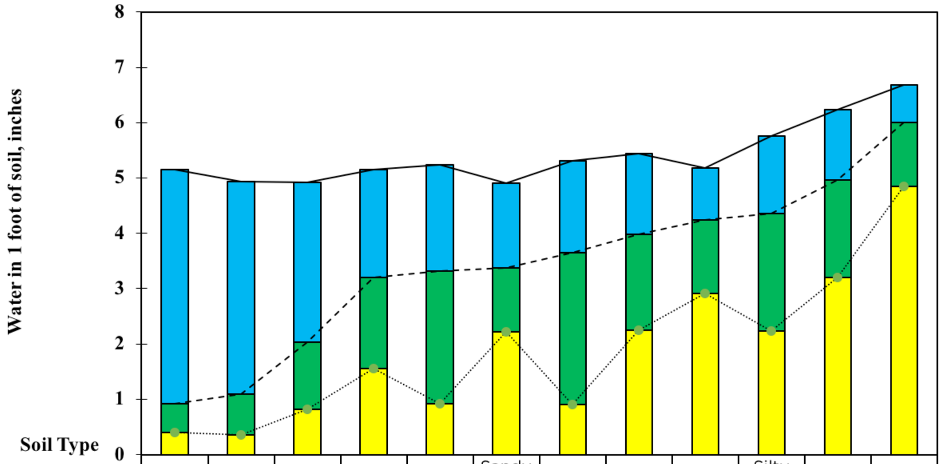


Figure 4. *Illustration of soil water reservoir and associated terms.*

Total available water (TAW) is the capacity of the available soil water reservoir. It depends on AWC and the depth plant roots can penetrate. For non-layered soil, TWC in the



	Sand	Loamy Sand	Sandy Loam	Loam	Silt Loam	Sandy Clay Loam	Silt	Clay Loam	Sandy Clay	Silty Clay Loam	Silty Clay	Clay
🟦 Gravitational Water (in/ft)	4.23	3.83	2.89	1.94	1.92	1.54	1.66	1.47	0.93	1.41	1.28	0.68
🟩 Available Water (in/ft)	0.53	0.74	1.22	1.64	2.40	1.15	2.75	1.73	1.33	2.13	1.76	1.15
🟨 Unavailable Water (in/ft)	0.40	0.36	0.81	1.56	0.92	2.22	0.90	2.24	2.92	2.23	3.19	4.85
—— Saturation	5.16	4.93	4.92	5.15	5.24	4.91	5.31	5.44	5.17	5.76	6.24	6.68
---- Field Capacity	0.92	1.09	2.03	3.20	3.32	3.37	3.65	3.97	4.25	4.36	4.96	6.00
···●··· Permanent Wilting Point	0.40	0.36	0.81	1.56	0.92	2.22	0.90	2.24	2.92	2.23	3.19	4.85

Figure 5. *Amount of water in 1 foot of soil (in/ft.) at saturation, field capacity, permanent wilting point and amount of gravitational, plant available and unavailable water in different soil types. All values are calculated using the procedure outlined by Saxton and Rawls (2006).*

crop root zone can be calculated by multiplying the AWC by the root zone depth.

Total available water = Available water capacity × Root depth

For layered soils, TAW can be calculated by summing the TAW of each individual layer by considering the AWC of each soil layer and thickness of each layer.

Table 2. Range of maximum effective rooting depth for fully grown crops (adapted from Doorenbos and Pruitt, 1977) under no-stress for common crops

Crop	Maximum Effective Rooting Depth* (feet)
Alfalfa	3.3 - 10.0
Barley	3.3 - 5.0
Beans	2.0 - 3.0
Cabbage	1.6 - 2.6
Carrots	1.6 - 3.3
Celery	1.0 - 1.6
Chickpeas	2.0 - 3.3
Citrus	2.6 - 5.0
Clover	2.0 - 3.0
Corn	3.3 - 5.6
Cotton	3.3 - 5.7
Cucumber	2.3 - 4.0
Grapes	3.3 - 6.6
Grass	2.0 - 3.3
Lettuce	1.0 - 1.6
Melons	2.6 - 5.0
Onions	2.0 - 3.3
Peas	2.0 - 3.3
Peppers	1.6 - 3.3
Potatoes	1.3 - 2.0
Safflower	3.3 - 6.6
Sorghum	3.3 - 6.6
Soybeans	2.0 - 4.5
Spinach	1.0 - 1.6
Strawberries	0.7 - 1.0
Sugarbeet	2.3 - 3.9
Sunflower	2.6 - 5.0
Sweet potatoes	3.3 - 5.0
Tomatoes	2.3 - 5.0
Wheat	3.3 - 6.0

*The maximum effective rooting depth values given represent the full expression of the genetic potential for root growth and are only found in uniform, fertile soils of low resistance to root penetration.

Plant root zone is the portion of soil profile that is generally considered for the crop water uptake. Root depth varies substantially for different crops and during the crop growing season. It's a function of crop, soil type, amount of irrigation applied, and precipitation.

Established perennial plants such as alfalfa, grasses, trees, and shrubs have relatively constant root zone depth; however, for irrigation scheduling, only effective rooting depth is usually considered, which is usually less than the maximum depth, where roots are found. It represents the depth of the soil profile where 80-90 percent of total root density is concentrated. For example, for sugarbeet, roots can uptake soil water down to a depth of 4-5 feet in loamy soils; however, effective root for sugarbeet in that soil is usually consider to be 2-3 feet.

Crops that are often irrigated excessively (or in wet conditions) tend to have a shallower root zone compared to dry conditions. The range of effective rooting depth for various crops is summarized in Table 2.

Many crops can use all the water between the FC and PWP, but soil water availability to plants, in general, decreases with decreasing soil wetness. This is because the gradient (and rate) for water to move from soil to plant roots at values near PWP is not as strong as the gradient at FC. The amount of water in the crop root zone that can be easily extracted by the crop, without experiencing any water stress, is called **readily available water (RAW).**

As a result, plants may experience water stress and reduced plant growth, development, and yield before the soil water status reaches PWP. To prevent water stress, irrigations are usually scheduled to replenish soil water to FC or near FC, when a fraction of the water between FC and PWP is depleted.

Plants can easily extract water between FC and a specific water content without any adverse stress effects. This specific water content is the **management allowable depletion** (**MAD**). As soil moisture decreases below MAD, flow of water from the soil to the roots is reduced and causes a reduction in crop yield potential. If the soil water reservoir is not replenished by irrigation or rain, the water content continues to decrease and eventually reaches a point a plant can no longer recover even if water is added.

MAD is primarily a function of crop stress tolerance, crop species and varieties, crop growth stage, soil type, management approach and climate. This value is small for sensitive crops such as vegetables and is larger for crops that can tolerate some water stress without affecting yields. A common level of MAD used for various crops is 45-50 percent. Table 3 shows maximum MAD values for different crop types according to sensitivity to stress under different climatic conditions (adapted and modified from Doorebis and Kassam, 1979).

For example, from Table 3, sugarbeet, part of the low crop group, a maximum crop evapotranspiration (ET) rate of 0.31 in/day (in Wyoming it varies from 0.25 to 0.35 in/day), means the maximum MAD is 45 percent compared to drybeans that have a maximum AD of approximately 28 percent. Thus, the criteria for management depend on the crop and the environmental conditions. For example, if the weather is relatively cool (low ET), a high percentage of soil water can be depleted before stress occurs. Conversely, if the weather is hot, (high ET) less soil water depletion could be tolerated before plants undergo stress.

WATER BALANCE

The soil acts as a reservoir to store water for crop use. As crops grow and extract water from soil to satisfy crop water use requirements (*crop evapotranspiration; ETc*), the stored soil water gradually depletes. The irrigator can keep track of this deficit (which is the net

Table 3. Estimated maximum allowable depletion (MAD) to maintain maximum yields of crops grouped according to sensitivity to water stress (adapted and modified from Doorebis and Kassam, 1979)

Crop Group	**High**	**Medium-High**	**Low-Medium**	**Low**
	Onion	Banana	Alfalfa	Cotton
	Pepper	Cabbage	Citrus	Sorghum
	Potatoes	Peas	Groundnut	Corn
	Other fresh/green vegetables	Tomatoes	Pineapple	**Sugarbeet**
	Sugarcane	Watermelon	Sunflower	Tobacco
	Rice	**Dry and edible beans**	Wheat	Millet
			Barley	
			Grapes	
			Soybean	

Maximum ET (inch/day)	0.08	0.12	0.16	0.2	0.24	0.28	0.31	0.35	0.4
The maximum allowable depletion (MAD) to maintain the maximum ET rates (above) for each crop group									
High %	50	43	35	30	25	23	20	20	18
Medium High %	68	58	45	40	35	33	28	25	23
Low-Medium %	80	70	60	50	45	43	38	35	30
Low %	88	80	70	60	55	50	45	43	40

amount of irrigation to apply) for irrigation scheduling. Tracking and predicting the soil water deficit (Di) level is critical to making irrigation scheduling decisions to maximize crop production. Soil water deficit can be estimated on a daily basis using the water balance approach, which is also called the soil water budget. It tracks the incoming and outgoing water from a field and is governed by the basic physical principle of **conservation of mass**:

Change in soil water = Water inputs - Water outputs

Water inputs include precipitation, irrigation from surface and ground water, upward inflow of shallow ground water, and outputs includes ETc, surface runoff, and deep percolation.

The water balance approach uses the water input and output information to calculate the Di and, hence, the crop water requirement. Among many approaches, a commonly used method to calculate ETc requires first the determination of *reference evapotranspiration* (*ETref*) and then adjusting it by a specific *crop coefficient* (*Kc*). ETref can be computed from the climate data (maximum and minimum temperature, relative humidity, solar radiation, wind speed) from nearby weather stations. Daily values of ETref can be obtained from Wyoming Agricultural Climate Network (WACNet; www.wrds.uwyo.edu/WACNet/WACNet.html).

The crop coefficient (Kc) incorporates the crop canopy characteristics and management practices. Each crop has different sets of specific Kc values depending upon the growth stages of the crop and field/crop management practices. Kc for a crop is the ratio of its ETc and ETref. The Kc can be thought of as the fraction of the reference crop ET that is used by the actual crop. Detailed information of both ETref and Kc can be obtained from the UW Extension bulletin "*Evapotranspiration: Basics, Terminology and its Importance, B-1293*."

Runoff is the portion of rainfall or irrigation water that directly exits the field horizontally without infiltrating into the soil profile. The portion of runoff that moves horizontally within the field from one location to another as a function of elevation difference in the field (slope/gradient) is called **run-on**. This movement of water within the field causes non-uniform distribution of the water on the soil surface that results in differences in soil water in the soil profile and affects soil water uptake, nutrient uptake, emergence, and plant growth. The amount of soil water that penetrates deeper than the plant root zone is **deep percolation**. Deep percolation is difficult to measure and is often assumed to be insignificant unless large rain occurs or large irrigation is applied. One goal of irrigation management is to avoid deep percolation, which is considered to be a major loss of water; however, in hydrological studies, deep percolation is considered the source of water that recharges the groundwater or aquifer. Different factors affect the amount and rate of deep percolation that includes the irrigation system (surface, sprinkler and sub-surface drip irrigation), irrigation and rainfall frequency and amount, soil type, field slope, etc.

SUMMARY

Sound agricultural water use and irrigation scheduling decisions require a fundamental understanding of basic soil water concepts. This publication presents an overview of the basics of soil water concepts and terms associated with the concepts. Common understanding of definitions and terms associated with soil water can aid better communication between agricultural producers, irrigation practitioners, extension personnel, researchers, and water management and regulatory agency personnel.

REFERENCES AND ADDITIONAL RESOURCES

Allen, R. G., L.S. Pereira, D. Raes, M. Smith. 1998. *Irrigation and Drainage Paper No. 56. Crop Evapotranspiration - Guidelines for computing crop water requirements*. Food and Agriculture Organization of the United Nations, Rome.

Doorenbos, J. and W.O. Pruitt. 1977. *Guidelines for predicting crop water requirements*. Irrigation and Drainage Paper 24. Food and Agriculture Organization of the United Nations, Rome, Italy, 179 pp.

Hillel, D. 1980. *Fundamentals of Soil Physics*. Academic Press, New York. 413 pp.

Irmak, S. and K. Djaman. 2015. *Basic Soil and Water Resources and Irrigation Engineering/ Agricultural Water Management and Related Terminology*. Nebraska, Extension EC2009.

Saxton, K.E. and W.J. Rawls. 2006. *Soil Water Characteristics*. Hydraulic Properties Calculator. Ver. 6.02.74. USDA Agricultural Research Service and Washington State University, Pullman, WA.

Sharma, V., J. Heitholt, and M. A. Islam. 2016. *Evapotranspiration: Basics, Terminology and its Importance. B-1293.* (http://www.wyoextension.org/agpubs/pubs/B-1293.pdf).

United State Department of Agriculture – Natural Resources Conservation Service (USDA-NRCS). Soil Texture Calculator (https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_054167)

GLOSSARY OF TERMS

Cation exchange capacity: The cation exchange capacity (CEC) of a soil is its capacity to exchange cations between the soil particles and the soil solution (the water in the soil). CEC influences the soil's ability to hold onto essential nutrients and provides a buffer against soil acidification.

Conservation of mass: A principle stating that mass cannot be created or destroyed. For example, in this case, it states that water can change forms to gas, liquid, or solid but the total mass of water remains constant, that is, the sum of all the mass of liquid, solid, and gas water is always the same.

Crop evapotranspiration: The crop evapotranspiration is the amount of water actually transpired from plants and evaporated from a soil surface under actual climatic conditions, under non-optimal soil, biological, management, and environmental conditions.

Irrigation: It is the process of supplying water at regular intervals by artificial means to agricultural fields for crop production.

Percolation: The downward movement of water through saturated soil layers. Percolation is responsible for groundwater (aquifer) recharge.

Plant transpiration: It is the biological-associated evaporation of cellular water from within the plant leaves. It is the process of movement of moisture through the plant roots to stems and leaves to the atmosphere through plant leaf stomata. Stomata are the microscopic pores on a leaf surface through which the plant exchanges water and gas to the atmosphere. This process is important for leaf cooling.

Reference crop evapotranspiration: This is defined as the rate of water loss by evaporation and transpiration from a healthy (free from water stress and diseases) hypothetical reference crop, for example, grass, and alfalfa.

Soil evaporation: It is a non-biological process during which liquid water converts to water vapor in the atmosphere from water bodies such as lakes, reservoirs, oceans, the soil surface, and from water droplets on plant leaves.

Soil tilth: It is the physical condition of the soil, especially in relation to its suitability for planting or crop growth. Factors that determine tilth include the formation and stability of aggregated soil particles, moisture content, degree of aeration, rate of water infiltration, and drainage.

Organic matter content: It is the fraction of the soil that consists of plant or animal tissue in various stages of breakdown.

B-1330
September 2018

UNIVERSITY OF WYOMING
EXTENSION

Issued in furtherance of extension work, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Bret Hess, Interim Dean/Director, College of Agriculture and Natural Resources, University of Wyoming Extension, University of Wyoming, Laramie, Wyoming 82071.