Bachelor of Biosystems Technology
Faculty of Technology
South Eastern University of Sri Lanka

BSE 11042 Principles of Irrigation

Soil Moisture Principles

Important soil characteristics in irrigated agricultural soils are

1. the water-holding or storage capacity of the soil
2. the permeability of the soil to the flow of water and air
3. the physical features of the soil like the organic matter content, depth, texture and structure
4. porosity
5. volumetric moisture content,
6. saturation,
7. dry weight moisture fraction
8. bulk density
9. specific weight.

These soil/soil water characteristics can be represented using a unit volume of soil (Figure 1). The following section gives the relationships on water properties based on the volumes and masses given in Figure 1.

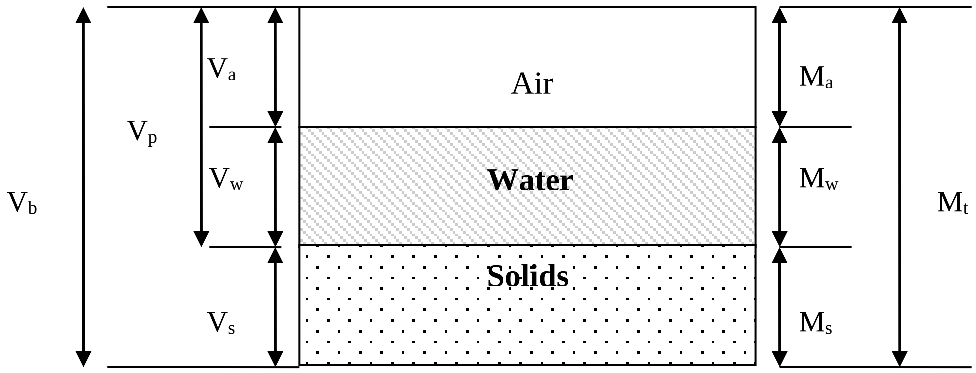

Figure 1. Schematic diagram of a soil block as a three phase system

Formulas for soil water properties

<u>Water content on mass basis (θ_m)</u>

$$\theta_m = \frac{mass\ water}{mass\ dry\ soil} = \frac{M_w}{M_s}$$

<u>Volumetric water content (θ_v)</u>

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$$\theta_v = \frac{volume\,water}{bulk\,volum\,soil} = \frac{V_w}{V_b} = \frac{V_w}{V_s + V_p} = \frac{V_w}{V_s + V_a + V_w}$$

Soil bulk density

$$\rho_b = \frac{mass\ dry\ soil}{bulk\,volume\,soil} = \frac{M_s}{V_b} = \frac{M_s}{V_s + V_a + V_w}$$

Soil porosity

$$N = \frac{Total\ pore\,volume}{bulk\,volume\,soil} = \frac{V_p}{V_b} = \frac{V_a + V_w}{V_s + V_a + V_w}$$

Air filled porosity

$$N_a = \frac{Air\ filled\ pore\,volume}{bulk\,volume\,soil} = \frac{V_a}{V_b}$$

Saturated water content (volume basis)

$$\theta_{vs} = \frac{Volume\,of\ water\ when\ saturated}{bulk\,volume\,soil} = \frac{V_p}{V_b}$$

Degree of saturation

$$DS = N\,\theta_{vs}$$

$$N = 1 - \frac{\rho_b}{\rho_s} \qquad where\ \rho_s\ is\ particle\ density$$

$$\theta_v = \theta_m \frac{\rho_b}{\rho_w}$$

Total available water

$$TAW = (\theta_{fc} - \theta_{pwp})\,RD$$

Soil moisture deficit

$$SMD = (\theta_{fc} - \theta_p)\,RD$$

Field capacity

The most common method of determining field capacity in the laboratory uses a pressure plate to apply a suction of -1/3 atmosphere to a saturated soil sample. When water is no longer leaving the soil sample, the soil moisture in the sample is determined gravimetrically and equated to field capacity.

A field technique for finding field capacity involves irrigating a test plot until the soil profile is saturated to a depth of about one meter. Then the plot is covered to prevent evaporation. The soil moisture is measured each 24 hours until the changes are very small, at which point the soil moisture content is the estimate of field capacity.

Permanent wilting point

Generally, at the permanent wilting point the soil moisture coefficient is defined as the moisture content corresponding to a pressure of -15 atmospheres from a pressure plate test. Although actual wilting points can be somewhere between -10 and -20 atm, the soil moisture content varies little in this range. Thus, the -15 atm moisture content provides a reasonable estimate of the wilting point.

Figures 2 and 3 represent the field capacity and permanent wilting point.

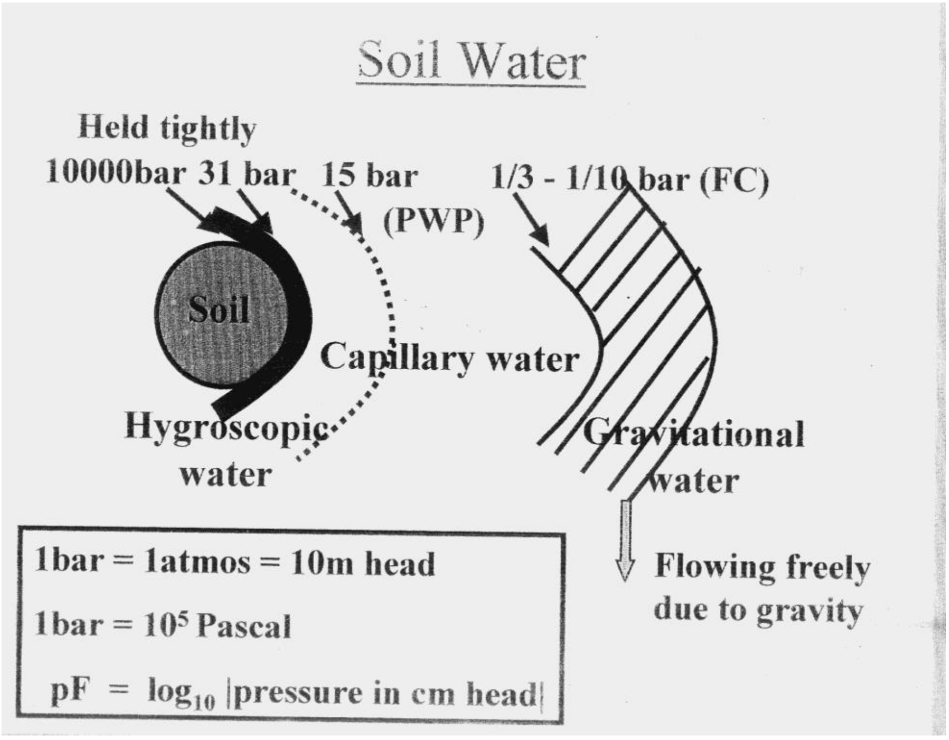

Figure 2. Representation of soil mositure

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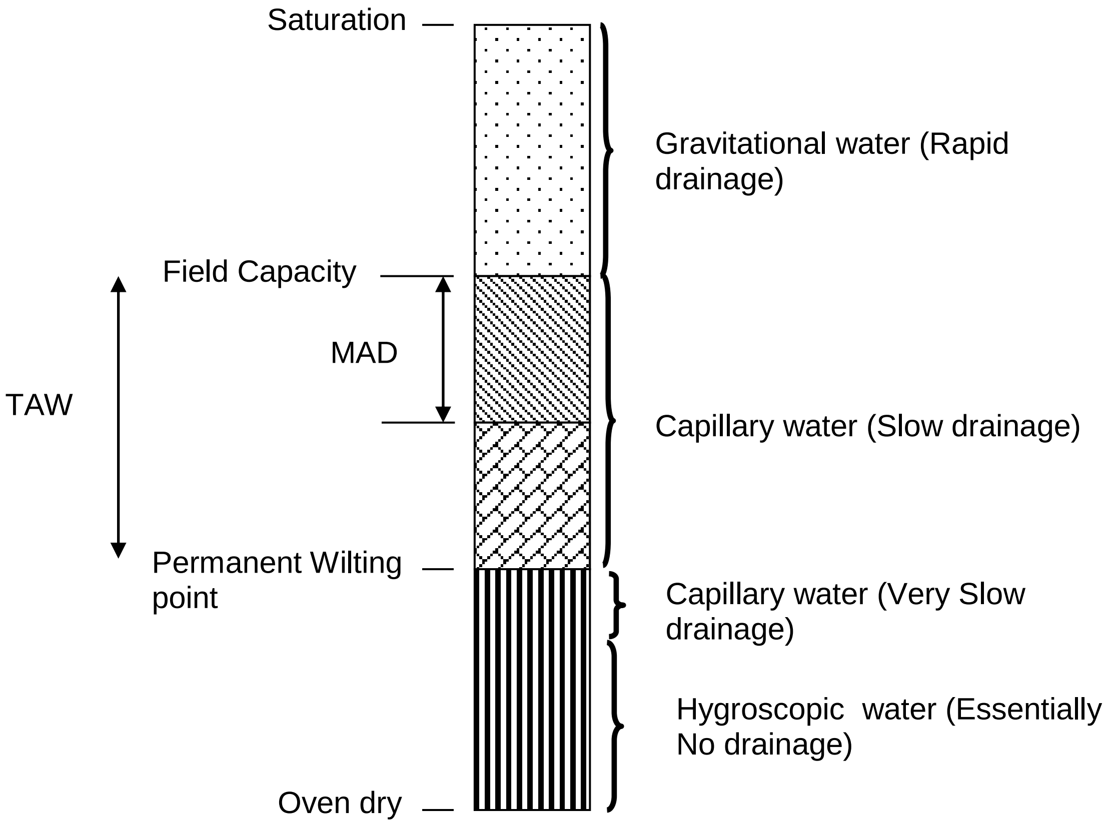

Figure 3. Schematic representation of soil moisture contents

Management allowed deficit
Degree of which the volume of water in the soil is allowed to be depleted before the next irrigation is applied.

The total available water, TAW, for plant use in the root zone is commonly defined as the range of soil moisture held at a negative apparent pressure of 0.1 to 0.33 bar (a soil moisture level called 'field capacity') and 15 bars (called the 'permanent wilting point'). The TAW will vary from 25 cm/m for silty loams to as low as 6 cm/m for sandy soils. Some typical values of TAW, field capacity, permanent wetting point and miscellaneous features have been given in various texts. A typical summary is shown in Figure 4.

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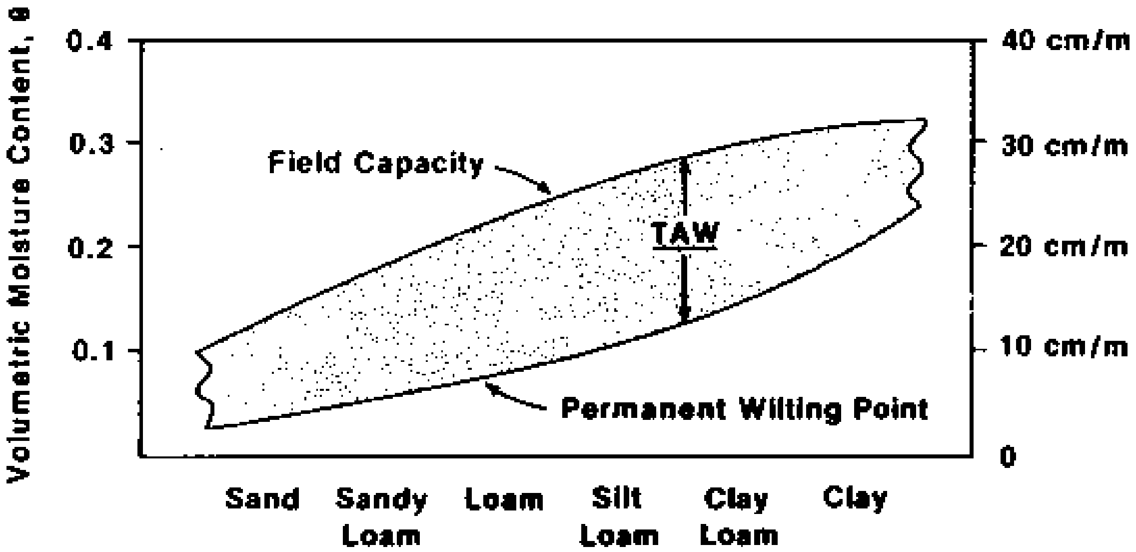

Figure 4. Relationships between soil types and total available soil moisture holding capacity, field capacity and wilting point (from Walker and Skogerboe, 1987)

Irrigation System Losses
• Leaks
• Evaporation
– Plant surfaces
– Soil surfaces
– Droplet
– Canals
• Runoff
– Excessive application
– Missing target area

Soil moisture measurements (Reference: FAO Irrigation and Drainage Paper 45)

The soil moisture status requires periodic measurements in the field, from which one can project when the next irrigation should occur and what depth of water should be applied. Conversely, such data can indicate how much has been applied and its uniformity over the field. As noted in the previous subsections, bulk density, field capacity and the permanent wilting point are also needed.

There are numerous techniques for evaluating soil moisture. Perhaps the most useful are gravimetric sampling, the neutron probe and the touch-and-feel method.

i. <u>Gravimetric sampling</u>
Gravimetric sampling involves collecting a soil sample from each 15-30 cm of the soil profile to a depth at least that of the root penetration. The soil sample of approximately 100-200 grams is placed in an air tight container of known weight (tare) and then weighed. The sample is then placed in an oven heated to 105° C for 24 hours with the container cover removed. After drying, the soil and container are again weighed and the weight of water determined as the before and after readings. The dry weight fraction of each sample can be

calculated. Knowing the bulk density, one can determine moisture contents and the soil moisture depletion.

ii. The neutron Probe

The neutron probe and scaler for making soil moisture measurements are illustrated in Figure 5. The neutron probe is inserted at various depths into an access tube and the count rate is read from the scaler. The manufacturers of neutron probe equipment furnish a calibration relating the count rate to volumetric soil moisture content. Field experience suggests that these calibrations are not always accurate under a broad range of conditions so it is advisable for the investigator to develop an individual calibration for each field or soil type. Most calibration curves are linear, best fit lines of gravimetric data and scaler readings but may in some cases be slightly curvilinear (van Baval et al., 1963).

The volume of soil actually monitored in readings by the neutron probe depends on the moisture content of the soil, increasing as the soil moisture decreases. The accuracy of soil moisture determinations near the ground surface is affected by a loss of neutrons into the atmosphere thereby influencing measurements prior to an irrigation more than afterwards. As a consequence, soil moisture measurements with a neutron probe are usually unreliable within 10-30 cm of the ground surface.

iii. Touch-and-feel

As a means of developing a rough estimate of soil moisture, the Touch-and-feel method can be used. A handful of soil is squeezed into a ball. Then the appearance of the squeezed soil can be compared subjectively to the descriptions listed in Table 1 to arrive at the estimated depletion level. Merriam (1960) has developed a similar table which gives the moisture deficiency in depth of water per unit depth of soil. Over the years various investigators have compared actual gravimetric sample results to the Touch-and-Feel estimates, finding a great deal of error depending on the experience of the sampler.

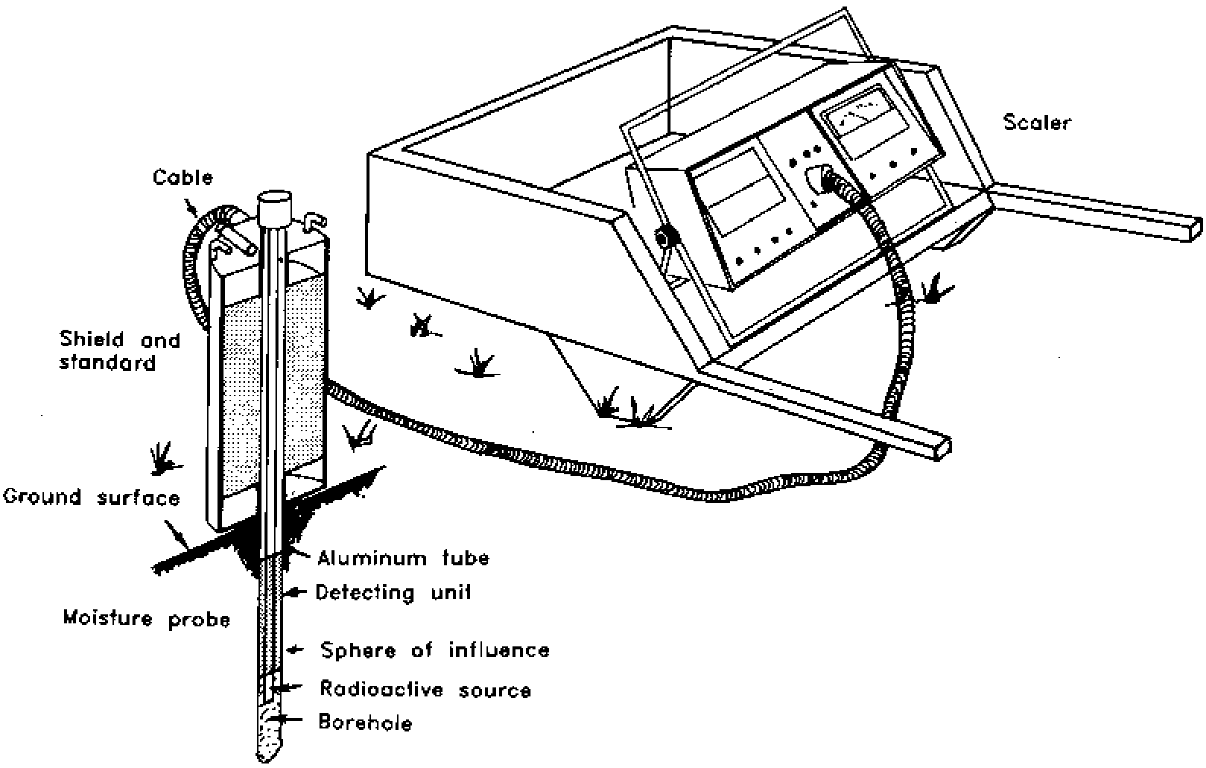

Figure 5. A neutron probe and scaler for soil moisture measurements (after Walker and Skogerboe, 1987)

Table 2 Guidelines for evaluating soil moisture by feel

Percent Depletion	Feel or Appearance of Soil		
	Loamy sands to fine sandy loams	**Fine sandy loams to silt loams**	**Silt loams to clay loam**
0 (field capacity)	no free water on ball* but wet outline on hand	same	same
0-25	makes ball but breaks easily and does not feel slick	makes tight ball, ribbons easily, slightly sticky and slick	easily ribbons slick feeling
25-50	balls with pressure but easily breaks	pliable ball, not sticky or slick, ribbons and feels damp	pliable ball, ribbons easily slightly slick
50-75	will not ball, feels dry	balls under pressure but is powdery and easily breaks	slightly balls still pliable
75-100	dry, loose, flows through fingers	powdery, dry, crumbles	hard, baked, cracked, crust

* A "Ball" is formed by squeezing a soil sample firmly in one's hand
A "Ribbon" is formed by squeezing soil between one's thumb and forefinger.