

A Review of Various Soil Moisture Measurement Techniques

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ABSTRACT: Accurate and appropriate moisture of soil is required for proper growth of plants and crops. Water is essential for survival of mankind, so water is required to be used with utter care and intelligence. Irrigation is the biggest consumer of water. This paper presents the overview of soil moisture. Various methods and techniques used for the measurement of soil moisture are discussed in detail.

KEYWORDS: soil moisture; water content; soil moisture measurement techniques.

I. INTRODUCTION

Relationship between soil and water is defined as soil moisture. It is also defined as the amount or content of water present in the soil. Water is the biggest resource for the development and sustenance of life on earth. The soil moisture is the most necessary component in the water cycle. It is important in small agricultural and in large scale modelling of our Earth's atmosphere. In recent time this valuable resource is reaching at danger level. There is unreliable and reduced water supply. So there is need to handle water with care. The maximum amount of water usage is in agriculture in form of irrigation. The plants should be irrigated only when they need water. So soil moisture monitoring is of great importance. In times of reduced and unreliable water supply, and in view of existing and upcoming water related regulations, monitoring of soil moisture represents a key method to help farmers matching irrigation application with actual soil water conditions and crop water use [1]. The amount of water used by a crop at any time depends, among other things, on moisture availability in the soil, air temperature, and soil temperature [2].

Accurate knowledge of field-scale variability of soil moisture is important for the management of irrigated agriculture [3]. Measuring soil moisture indicates if there is a shortage of water that can affect the yield or there is excessive water application that can result in leaching of nutrients below the root level. The soil moisture status requires periodic measurements in the fields, from where one can project when the next irrigation should occur and what depth of water should be applied. All this raises the need for soil moisture measurement techniques.

II. HOW WATER IS HELD BY SOIL

The water-holding capacity of a soil depends on its type, organic matter content, and past management practices, among other things [4]. Soil can be classified into dozen of texture classes. This classification is dependent on the sand, silt and clay percentage. Sand is the largest, then comes the silt and smallest particle is clay.

The USDA (United States Department of Agriculture) identifies soil types according to a soil texture triangle. This chart gives different names to different combinations of clay, sand and silt.

The water holding capacity of soil is given by its texture and the organic matter present in the soil. Water is held by soil according to the surface area of particle size. The smallest particles have much larger surface area. The larger surface

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area allows the soil to hold more amount of water. The organic matter present in soil also influences the water holding capacity of soil. More the organic matter more will be water holding capability and vice-versa.

III. DIFFERENT METHODS USED IN MEASURING SOIL MOISTURE

The level of water in the soil can be expressed as soil water content or water tension (potential). Soil water content can further be classified in three aspects: percentage water by weight, percentage water by volume and last inches of water per foot of soil. Water tension describes how tightly the water molecules are attached to soil. The soil moisture can be determined by two ways. One is feel and appearance method and second one is using sensors and meters. In the earlier times when the technology was not much developed, the farmers use their hands to know that how much water content present in soil. From the appearance of soil, they tried to guess the water content. This method was approximation method. As the technology gets advanced, new technologies emerged and new sensors and meters come into origin. These methods provide accurate results and are quite efficient. Proper placement of sensors is also critical to represent soil moisture in the root zone and obtain meaningful data for effective irrigation management [1]. Therefore, proper care should be taken while placing sensors in the soil.

IV. CONCEPTS RELATED WITH SOIL MOISTURE

Saturation Point: This is that point when excess amount of water is present in the soil. This is also known as the readily available water. At this point the plants can easily extract the water from soil.

Refill point: As the amount of water reduces due to evaporation and removal of water from soil, there occurs the condition when the plants cannot easily extract the water from soil. Because the small amount of water present in the soil cling more tightly to soil particles and in small pore spaces. This condition of soil is refill point.

Permanent wilting point: When the soil continues to dry, there is very little amount of water is present in soil that cannot be extracted from soil by plants roots. This condition of soil is known as permanent wilting point.

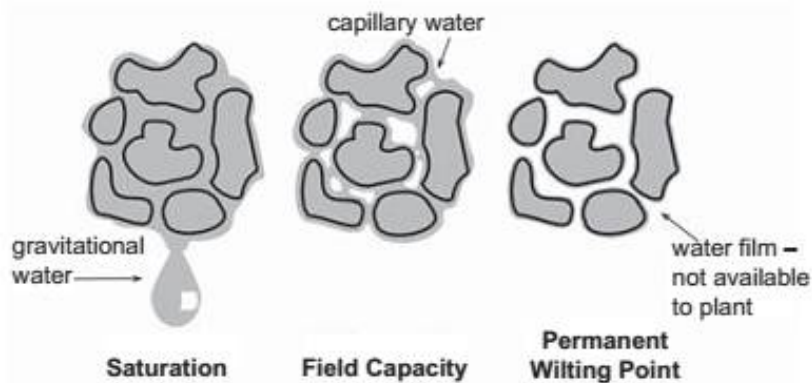


Fig 1 Different points of soil moisture [5]

V. SOIL MOISTURE MEASUREMENT TECHNIQUES

The measurement techniques are based on two concepts; one is volumetric and second is based on water tension. Volumetric involves calculation by mass or volume. It gives output in the form of present content. The water tension measurement involves the energy measurements. Water tension is measured in energy/mass of soil. Units are joules/kg or kilopascal. Using above concepts the techniques are classified as follows:

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1. Gravimetric method
2. Neutron moisture meters
3. Time domain reflectometry
4. Frequency domain reflectometry
5. Tensiometers
6. Gypsum blocks

Gravimetric method: Gravimetric is the term related to analysis based on quantitative measurement of mass or solid. In gravimetric method of moisture measurement, the moisture content is expressed by ratio as weight of water to the weight of dry soil. This is very basic method of soil moisture calculations. Different soil samples are taken from any depth from any farm or garden. The collected samples are put into an air tight container. The samples are weighed and then heated in oven at temperature 100-110°C, more specifically at 105°C. The heated samples are left for 24hours, so that no more content of water is present. Then dried soil samples are weighed and at the end the moisture content is calculated using formula

$$\text{Moisture content} = \frac{(\text{weight of original sample} - \text{weight of dried soil})}{\text{weight of original sample}} \times 100$$

Advantages: Gravimetric technique is accurate and simple, and involves low cost process.

Disadvantages: Tedious method, involves more labor, destructive for soil and sometimes very difficult to take samples from rocky soil.

Neutron moisture meters: Neutron probe moisture meters involve the detection of soil moisture using radioactive element (americium 241). A probe is fed deep into the soil and connected to power supply, microcontroller, display and keypad via wire. The probe contains a source and detector. The fast neutrons are emitted by the source and the detector detects the neutrons that come back after collision and absorption with nuclei of soil and water. The number of neutrons that come back to probe depends upon the hydrogen and oxygen atoms present in the soil. When a neutron comes into contact with the hydrogen atom, it loses energy. So this collision slows down the emitted neutrons, some loses energy to such extent that they cannot come back to the detector. Boron tri fluoride gas is used in the detector. Gas emit photons when it absorbs the neutrons, so the number of neutrons that come back can be calculated by using an electronic circuit that counts the photons emitted by Boron trofluride .

Advantages: Neutron probe method gives fast and reliable measurement. Repeated measurements can be taken at any depth of soil and at any location.

Disadvantages: The major disadvantage of neutron moisture meter is involvement of radioactive element. This radioactive element requires extensive care to handle and licensed, efficiently trained operator. The equipment is of very high cost and extensive calibration is required. The presence of salts also affects the readings of meter.

Time domain reflectometry systems: The time domain reflectometry system measures the travel time of the electronic pulse through the waveguides (two or more probes), which is surrounded with the soil. The water content of the soil is calculated by using the travel time readings. The TDR system consists of pulse generator that generates a square wave, and an oscillator that captures the reflected pulse, from many points along the probe. The probes are inserted into the soil; the travel time depends upon the complex permittivity of the soil [6]. The reflection of the original signal will occur when there is any change in the impedance. The water present in the soil will change the dielectric constant of the soil. Due to change in dielectric the impedance variations occurs and affect the shape of the reflected signal. The reflected signal's shape is used to obtain the information about the water content present in the soil.

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Advantages: Simple, accurate and continuous measurements are provided. TDR does not need any calibration not affected by salts. Probe of any length can be used, so more deep soil readings can be taken.

Disadvantages: It involves complex electronic equipments. It is an expensive system.

Frequency domain reflectometry: Frequency domain reflectometry uses capacitance probes to measure the moisture. The moisture is calculated by considering the dielectric constant of the soil. The dielectric constant of any material is defined as capacity to transmit the electromagnetic pulses or waves. The dielectric constant of water is much higher than soil. Two electrodes are embedded into the soil and soil acts as dielectric medium. The electrodes are given voltage supply, due to presence of water the dielectric of soil changes. Because of which the frequency oscillations occur, at a certain point resonance occurs and the resonance frequency value is used to calculate the water content in the soil. More the water, smaller will be the resonant frequency.

Advantages: FDR is more accurate method as compared to TDR. It is not affected by the salinity levels, gives better resolution. The design of probe is flexible and robust. It is an inexpensive method compared to other methods. Last but not the least, it is quite easy to interface FDR soil moisture sensor with a microcontroller.

Disadvantages: Installation requires extensive care. Presence of air gaps also affects the accuracy of readings.

Tensiometers: Tensiometers are the devices used to sense the water tension inside soil. They provide useful information for planning irrigation and managing soil moisture levels to best advantage to maintain healthy turf and landscape plants [7]. The principle of tensiometer is measurement of soil tension that is, the force that is required by the plants to acquire water from soil. A tensiometer consists of a transparent glass tube which is equipped with a ceramic cup at the end tip. This ceramic cup is permeable. The glass tube is filled with water. When the glass tube is put into the soil at the root level, the water is allowed to move out through the permeable ceramic tip. The water will move out only when the soil is not saturated i.e. the water content in the soil is not highest. When the water present in the tube goes down into the soil, a vacuum is generated inside tube. The vacuum generates tension inside the tube. A vacuum gauge connected with the tube, measures the value of the tension. More water in the soil less will be the tension and vice versa. So, the reading of gauge gives the idea that how much water is present inside the soil. The readings are in kpa (kilopascals) or centibars. For more accurate results tensiometers are inserted into the soil at the root level.

Advantages: It provides direct and continuous readings. No power supply is required. Variable length tensiometers are available to take any variable depth moisture measurement. Minimal skill is required to read reading of gauge. It is an inexpensive system.

Disadvantages: The response time is relatively slow. Careful handling of equipment is required. It requires frequent maintenance.

Gypsum blocks: Gypsum block is composed of calcium sulfate dehydrates. Its ability to absorb water and to come into equilibrium with medium makes it a convenient soil moisture sensor [8]. Gypsum block is cylindrical or rectangular in shape. The electrodes are embedded into the block. The dry gypsum block is inserted into the soil. Small voltage is provided to the electrodes. The electric resistance between the electrodes measures the tension of the soil. If water is present in the soil, it is absorbed by gypsum block, and comes in equilibrium with soil water. Hence, resistance between the electrodes will decrease and vice versa, and gives the information about the water content of soil.

Advantages: Gypsum blocks are inexpensive and are reliable. They don't require much maintenance and no calibration is required.

Disadvantages: Only useful in refill point of soil. This can't measure moisture when soil is in saturation. The response time is very less.

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VI. CONCLUSION

Accurate and appropriate moisture of soil is required for proper growth of plants and crops. Also, water is essential for survival of mankind, so this is required to be used with utter care and intelligence. Irrigation is the biggest consumer of water. So farmers need to use water very carefully. Field can neither be under irrigated nor over irrigated. For this purpose the soil moisture measuring techniques can help them a lot. This paper provides deep information about various soil moisture measurement methods, techniques and science behind them. All the techniques have their own advantages and disadvantages. Comparing all techniques, it can be concluded that when one has to make a soil moisture system using microcontrollers and embedded system, the frequency domain reflectometry soil moisture sensor is easy to interface. These can also be used in implementing wireless sensor networks in agriculture.

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