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The Definition and Monitoring of Soil Water Content

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Abstract

Agriculture is the biggest water consuming industry by with 70% among other sectors. Overuse of water means wasting water, which is a critically important for natural resources. Similarly, using less water than necessary leads to decrease in vegetative production. Therefore, it is extremely important to determine the accurate amount of water to be used in irrigation. For this purpose, it is a necessity to monitor and determine the amount of water already exists in the soil. Many different methods have been developped to be used in for the determination of soil water content. In this research, three different methods have been investigated, and these methods are the most commonly used ones. The first method is gravimetric, the second one is time domain reflectometry (TDR) and the third is neutronmetre. While Gravimetric method can be used to directly determine the soil water content. TDR and neutronmetre methods are used to indirectly measure the soil water content. Gravimetric method is used in for calibrating the TDR and neutronmetre methods. The indirect measurement methods have been developed to make them more practical in implementation compared to the direct measurement methods. In spite of all these advantages, the indirect measurement methods may not come up with the results as accurate as those of direct measurement methods. Moreover, the cost of the tools used in the indirect measurement methods is much more than that of the tools used in direct mesurement methods. However, it may not be appropriate to use a method dependent on one single criteria. With this regard, this study aims to discuss the superiority and shortcoming of different methods to be used in determination and monitoring of soil water content.

Keywords: Soil water, neutron probe, gravimetric method

Toprak Su İçeriğinin Belirlenmesi ve İzlenmesi

Özet

Tarım, toplam suyun yaklaşık %70'ini tüketen en büyük su kullanıcı sektörü durumundadır. Aşırı su kullanımı kritik bir doğal kaynak olan suyun israf edilmesi anlamına gelmektedir. Benzer bir şekilde, az su kullanımı da bitkisel üretimde azalmalara yol açmaktadır. Bu nedenle, tarımsal sulamada bitkiye verilmesi gereken suyun miktarının belirlenmesi son derece önemli bir durumdur. Bu amaç için, toprakta bulunan suyun miktarının bilinmesi ve izlenmesi gerekmektedir. Toprak su içeriğinin belirlenmesi amacıyla çok sayıda yöntemler geliştirilmiştir. Bu makalede, toprak su içeriği miktarının belirlenmesi için yaygın olarak kullanılan üç farklı yöntem ele alınmıştır. Birincisi gravimetrik, ikincisi time domaition reflektrometre (TDR) ve üçüncüsü ise nötronmetre yöntemidir. Gravimetrik yöntem ile toprak su içeriği doğrudan doğruya belirlenebilmektedir. TDR ve nötronmetre ise toprak su içeriğini dolaylı ölçebilen yöntemlerdendir. TDR ve nötronmetre yöntemlerinin kalibrasyonlarında da gravimetrik yöntem kullanılmaktadır. Dolaylı ölçüm yöntemleri doğrudan ölçüm yöntemine göre uygulamada daha pratik olmaları ve daha hızlı sonuç vermeleri amacıyla geliştirilmiş yöntemlerdir. Bu avantajlarına karşılık doğrudan ölçüm yöntemi kadar yüksek oranda doğru sonuç vermeyebilirler. Ayrıca, doğrudan ölçüm yönteminde kullanılan aparatlarla kıyaslandığında dolaylı ölçüm yöntemlerinde kullanılan cihazlarının maliyetleri çok daha yüksektir. Ancak, tek bir kritere bağlı olarak yöntem seçilmesi doğru olmayabilir. Bu bağlamda ele alınan bu çalışmada, toprak su içeriğinin belirlenmesi ve izlenmesinde kullanılabilecek farklı yöntemlerin üstünlük ve eksikleri tartışılmıştır.

Anahtar Kelimeler: Toprak suyu, nötronmetre, gravimetrik metod

Introduction

Soil is a lively, heterogenous and dynamic system in which all living creatures shelter, plants grow. As it has been the most important habitat for plants to grow, knowing about the basic relationship between soil and water in modern agriculture has been concerning by diversified amouth of people, such as plant breeders, forest engineers, environmental engineers, civil engineers as well as those being engaged in soil and irrigation. Depending on this, the measurement of the soil water content has been a basic requirement for those engaged in soil and water conservation and many environmental and engineering works (Çetin, 2003).

Water in agricultural production has a significant role with regards to yield. The rate of water consumed in agricultural irrigation is 70% among other usages. According to the data provided by Food and Agriculture Organization (FAO), 17% of the total agricultural land can be irrigated in the world.

The amount of foods produced in the irrigated farming lands is between 30% and 40% of the total agricultural production. The increase in the demand for domestic and industrial lands in the future will increase the risk of lack of water spared for irrigation purpose in the future (Lazarova and Asano, 2005). 7 % of the total world population lives in the regions which lack adequate water. This rate is guessed to rise up to 67% by 2050. According to the population distribution data released by United Nations, world population has increased 125% following 1950. Besides, world population is expected to increase 67% as suggested by some optimistic projections. Most of this increase is foreseen to happen in developing countries (Fischer and Heilig, 1997).

Water shortage has raised suspicion about whether enough food will be produced or not in the future as a consequence of improper irrigation methods used in agriculture and the social and environmental pressures led by big water projects in the near future. It has been a common debate in recent years; that is, whether irrigated farming will be sustainable or not is one of the most improtant problems of agriculture in future years. The general approach in irrigated farming can be generally summed up “less water, more products”. (Klohn and Wolter, 1998). With this regard, knowing about the amount of water in the soil and monitoring it are significant issues.

The methods used in the measurement of Soil Water Content.

The accurate and delicate measurement of soil water content requires a lot of environmental and engineering works basically for the irrigation method. For water management purposes, the following factors should be inspected adequately, such as the sufficiently meeting the need of plant for water in soil water content measurements, not washing up soil nutrient elements through excess irrigation , saving water, keeping the level of groundwater under control, the prevention of pesticides and fertilizers from mixing in underground water. Soil water content measurements are done through direct measurement methods or indirect measurement methods.

The Direct Measurement of Soil Water Content

Some soil sample is taken using an appropriate pipe, and it is weighed without letting it lose its humidity, and thus the soil weigh is found out as well as the water content. This is called as “wet weigh” of the measured soil. Following the wet weigh of the soil sample, the sample is dried in a drying machine in 105^0C for 24 hours till it reaches a stable weigh. When the sample soil weigh reaches a stable point, it is taken out of the drying machine without letting it gather moisture. The measured value is called as “the dry weigh of the soil sample”. The difference between the dry and wet weigh of the soil sample is the amount of the water content in the soil. This method is called as gravimetric method. The value related to the water content found out in the sample soil does not mean much without knowing about the land capacity of the sample soil and wilting point of the sample soil because of the difference between soil profiles.

Whereas the soil water content value, which is found out depending on the dry weigh value of soil as a consequence of the difference between soil profiles, tells a lot about the land capacity, the same value can be a value below even the wilting point in a different soil profile. The weighed soil water is multiplied with the bulk density and thus volumetric water content is found out. Then soil water content can be expressed in depth (cm and mm).

The gravimetric method provides a basis for indirect mesuring methods and tools. The calibration of the indirect measurement methods and tools is done based on the data obtained through direct measurement methods.

The direct measurement methods require a lot of labour force, and it is also very time consuming. It ruins the nature of the soil where the sampling is done; therefore, it is not appropriate for narrow lands where a lot of sampling work is required. Besides, the sampling results are evaluated at least in 24 hours.

Indirect measurement methods

Indirect measurement methods have been developed as gravimetric method takes too much time and labour force. Besides, gravimetric method has some other disadvantages, such as giving damage to the roots of the plants in plantations, ruining the nature of the parcel where trials and studies are carried out.

The use of indirect methods of measurements has become more common as it provides faster data acquisiton and requires less labour force. In indirect methods of measurement, the soil water content can be measured with the help of permanent sensors and tubes mounted in the land. The biggest advantage of these methods is that, once the relevant sensors and tools are mounted in the land, we can carry out repeated measurements without any spoilage in the soil and with very little labour force (Öztaş, 1997). The two most important of these are neutronmeter and TDR.

Neutronmeter method

Neutronmeter technique can work with a bigger volume compared to the other methods used in agricultural soil water content measurements (in about 30 cm semidiameter-land). Neutronmeter is considered to be a reliable method which is mostly prefered because it can carry out repeated measurements without making any damage to the soil structure and it gives very quick results. The devices consist of a radioactive source which emits quick neutrons, an aliminium tube, an electronic counter counting the slowing down neutrons and a cable connecting these two to one another.

As neutron source, alpha particle emitter (for example, americium and radium) and thin beryllium powder were used. Alpha particles collide with beryllium atom particles, fast neutrons with higher energy potential. During the measurements, the searcher is lowered to the predetermined depth and fast neutrons are emitted by the neutron sources within the soil. The neutrons interact with the hydrogen atoms within the soil water and lose their energy and slow down. The slow neutron collisions determined by the slow neutron detectors are primarily pushed up in the searcher. The pushed up collisions are sent to the electronic counter system. Each counting result is equal with the collision happening when a slow neutron reaches the detector, and micro processers convert the raw data into the countings in minutes (cpm) or in seconds (CPS). The cpm value obtained from the neutrometer does not mean much on its own. Therefore, this data needs to be explained with one of the soil humidity expression modes. With this regard, the values counted by the device need to be calibrated with the values obtained with gravimetric methods.

Neutronmeter calibration and standard counting

In an appropriate part of the land, which is considered to be the exact sample of the rest of the land, the neutron measurements are done under various humidity settings and matched with gravimetric sampling values simultaneously. It is easier to calibrate the soils having homogenous structure. However, it is strongly suggested to increase the frequency of the humidity intervals and the number of sampling in the heterogenous soils with a lot of stones, pebbles and layers. A study investigating neutronmeter calibration reveals that soil texture and soil bulk density have significant effects on neutron calibration (Lal, 1974). It is expected to see the humidity change values in countings and gravimetric samplings similar to the humidity changes in the soil in agricultural period. This is very time consuming because humidity values tend to decrase from the beginning till the end of plant growth season. To be able to catch this tendency, the calibrated land needs to be saturated with water. When the soil is saturated with water, sampling works should start and the humidity values which tend to decrase in time should be measured in certain intervals with gravimetric sampling and neutron measurements. Neutronmeter calibration is correlated with the soil content with regards to volume and neutronmeter counting values (cpm).

Neutronmeter measurements may show deviation under some certain conditions. Some organic elements, such as plant root system within the soil, boron, chlorine, megnesium, cadmium, lithium, may lead to lower counting values than needed by slowing down, spreading or absorbing neutrons. In such cases, if there is a clear heteoregenity in the land, the calibration balance needs to be repeated for each layer within the soil. Within the first 30 cm of the soil, errors may occur as a consequence of neutron flux. Some other measurement methods can be used within the first 30 cm of the soil surface. Besides, changes in air temperature were found to have affected the neutron measuremennts (Evett, 1998). It is recommended that measurements should be done in the temperatures when standard measurements as much as possible. It is enough to do the measurements for 30-32 seconds in low measurement values, for 15 seconds in high measurement values (Anonymous, 1998).

Time domain Reflectometry (TDR)

Time Domain Reflectometry (TDR) method was developed by Davis and Chudobiak (1975) based on the procedure suggested by Felner-Feldegg (1969). TDR is used in the determination of the dielectric coefficient with the help of the electrodes installed in any objects.

The dielectric coefficient is found out by measurement the diffusion time of electromagnetic waves coaxial (specially designed to conduct high frequency signals) TDR probes (generally made of stainless steel and brass). Some of the electromagnetic waves sent from the source pass through coaxial cable to the probe and reflects back because of the impedance difference. The rest electromagnetic wave reaches till the edge of the probe and then reflects back. With the help of an oscilloscope connected to the coaxial cable, the return duration of the electromagnetic wave is measured (Fellner-Feldegg, 1969).

The operating principle of the TDR device is to convert the measured time into the relative vectorial spreading coefficient, which is a fraction of light velocity by correlating it with the distance that electromagnetic wave have covered on the probe. In other words, it is something closely related to measurement the dielectric coefficient of the probe in the setting where the measurement was carried out, depending on the speading speed of the electromagnetic wave on the probe. TDR is also used to measure the dielectric coefficient, which means that we measure the soil water content indirectly. As the dielectric coefficient of water is bigger than that of the other soil components, we can find out the soil water content by measuring the dielectric coefficient of humid soil (Hoekstra and Delaney, 1974).

One of the biggest advantages of TDR probe is that it can easily measure the humidity of surface soil contents. Measurement the humidity levels through gravimetric method can ruin the surface, and it is also very time consuming and onerous. Neutronmeter method works in surface soils. In the case when there is a need for a more frequent sampling, it is possible to do the measurement by fastening the metal sticks along the profiles and connecting the cable edges to the TDR units on the soil surface when necessary (Öztaş, 1997).

Conclusion

In order for water and soil resources to be used in a more productive ways, it is an unavoidable situation to develop new devices and new methods of measurement soil water content. Every device developed for this purpose has some superiorities and shortcomings as suggested by the comparisons. Gravimetric sampling method is different from other methods as it is the one to give the most accurate results and as it is the base for the calibration of the indirect measurement methods. On the other hand, a lot of indirect methods have been developed to measure soil water content.

Neutronmeter and TDR methods, which are among the indirect measurement methods, may show deviation when used in marginal soils depending on the physical, chemical and organic components of the soil. Therefore, there is a need for the physical and chemical analysis of the soil not to lead to any error in the measurements. During the calibration, these components should be considered. In addition to that, when a need arises for a new method to find out soil water content, for a new method the following factors need to be considered very carefully, such as available physical and financial facilities, adequate labour force, the size of the land to work on, the number of samplings, knowledge and experience, the chracteristics of the land where measurements will be carried out.

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