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A COMPARISON OF THE GRAVIMETRIC AND TDR METHODS IN TERMS OF DETERMINING THE SOIL WATER CONTENT OF THE CORN PLANT

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Abstract

This study, conducted in Kahramanmaras province with a view to watering the corn plant on a timely basis so as to avoid the plant going through water stress, aims to establish the relationship between the direct (Gravimetric) and indirect -namely the Time Domain Reflectometry (TDR) measurement methods and present the advantages and disadvantages of the said methods. In both methods, the results have been presented based on the calibration curves that have been found to determine the soil water content in 15, 45 and 70 cm deep soil (for 15 cm depth R^2=0.91, for 45 cm depth R^2=0.98, and for 70 cm depth R^2=0.84). As a result of the statistical analysis the relationship between the gravimetric and TDR measurement methods was found to be significant ($p<0.05$). According to this result, it was established that there was a strong relationship between the measurements and that the TDR equipment yielded very good results in determining the soil water content and the difference between the measurements performed by gravimetric and TDR equipment s was found to be statistically very significant in terms of reducing labor and time ($p<0.01$). According to the analysis result, the TDR measurement method was found to have saved a significant amount of time and labor as compared to the gravimetric measurement method. In the end, the effectiveness of using TDR as an indirect method for minimizing water consumption in the agricultural areas and thereby yielding more crops by preventing soil salinity has been established. It was concluded that the use of TDR will contribute positively, in many respects, to the national agricultural economy and the Turkish farmer thanks to the minimization of the labor and water costs and the more productive use of the water resources.

Key words: *soil water content, TDR (Time Domain Reflectometry), gravimetric method.*

INTRODUCTION

Today, the technological developments are considered as important in increasing efficiency as such indispensable elements as labor, capital and natural resources. Technological developments result from scientific works and studies (Uçan, 2001; Tolk et al., 2015). The methods employed in determining the soil water content are divided into groups, namely the direct methods that rely on the principle of determining the body of water and the indirect methods that rely on the principle of measuring any soil property that depends on the soil water content (Muñoz-Carpena, 2006; Uytun et al., 2013).

The direct method is that of the gravimetric method whereby the water inside the soil is evaporated from a soil sample and taken away from the soil through washing and chemical reactions and the amount thus taken away is determined. The biggest disadvantage of the direct method is the destruction brought about on the trial parcels and soil profiles due to the impossibility of taking more than one sample from each spot. Taking multiple samples from the same spot may lead to the creation of macro pores on the soil which, in turn, result in the change in the soil humidity regime. Another disadvantage of the said method is that the differences in the humidity contents of the soil samples taken at different times reflect both the variation in the soil water and the variation resulting from the heterogeneous quality of the soil. Moreover, the fact that the result obtained through this method will not be able to be assessed in a real timeframe, but it will take time to carry out the measurement is considered as another drawback of this method. The most important feature of the gravimetric method is that it is a standard method applied for the calibration of indirect methods (Kutilek and Nielsen, 1994; Zazueta and Xin, 1994; Demiralay, 1977; Gardner, 1986; Tanrıverdi, 2005; Uytun et. al., 2013; Zhou et. al., 2014; Çapar and Uçan, 2015).

In indirect methods, the change in certain physical and physiochemical properties of the soil depending on the amount of water available is taken as the basis. In most of those methods, the soil humidity is easily determined either through the sensors that have been permanently placed in the soil or the sensors that have been placed in specially opened pockets in the soil at the time of the reading. The most important feature of the indirect methods is that once the equipment is installed in the soil, they facilitate frequent and constant measurements in the same spot in real time and in a conveniently accessible manner without allowing any deterioration in the soil property and having to spend long periods of time. Moreover, the soil water content will have been determined once the sensor is read. Among the indirect methods, electrical conductivity method, thermal conductivity method, neutron method, gamma ray weight loss method and the recently popularized TDR (Time Domain Reflectometry) method are regarded as important methods.

TDR equipment determines the soil water content by performing dielectric measurement through its probes (Quaknin et al., 2015). The studies conducted by various researchers for the purpose of measuring the soil water content in various different soil textures report that the use of TDR equipment is an acceptable method in measuring the soil water content as it yields reliable and accurate results (Hart et al., 1994; Van Clooster et al., 1995; Frueh and Hopmans, 1997; Hart and Lowery, 1998; Nissen et al., 1998; Irmak et al., 1999; Noborio et al. 1999; Huisman and Bouten, 1999; Robinson et al., 1999; Thomsen et al., 2000; Tanrıverdi, 2005; Tülün, 2005; Küp, 2009; Zhou et al., 2014; Quaknin et al., 2015; Chung et al., 2016; Schwartz et al., 2016).

This study aims to determine the utilization of TDR as a reliable method by determining the calibration curve of the TDR equipment, which is used as an indirect method in determining the soil humidity content, and present the advantages and disadvantages of preferring this particular method by comparing it to the gravimetric method.

MATERIALS AND METHODS

Measurements were conducted in a corn field located in Kahramanmaras central county consisting of 18 parcels of 420 m^2 surface area for the purpose of determining the irrigation water requirement by using gravimetric and TDR methods in the spots of the said field, each representing 18 parcels. Measurements were taken from the 15, 45 and 70 cm deep soil before and after the irrigation and conducting checks.

For the gravimetric method, a total of 54 soil samples were taken from 3 different depths using augerhole hand brace, and the humidity content of the samples taken was identified in the laboratory. On the other hand, uncouted probes were used for the purpose of performing measurements with the TDR equipment. The probes were left in the parcel until the end of the trial in order to avoid the formation of macro gaps in the parcels and making measurements in the same spots, and in such a way as to represent each and every parcel.

The samples taken from the parcels using augerhole hand brace for the gravimetric method were taken into a spoiled soil sampling container so as to avoid losing its humidity content and the container was firmly sealed around the lid by a band. The samples brought to the laboratory from the field were weighed by precision scales and the wet weight of each sample was determined. After having identified their we weight, the samples were dried in the soil drying ovens at 105°C for 24 hours until their weight became stable, and the weight found by the end of the drying process was designated as the dry mass of the soil this method, the reduction in the weight of the soil sample is that of the mass of the water which is lost through evaporation during the drying process. The soil water content based on weight (mass) is;

$$Pw = \frac{YA - KA}{KA} x100$$

In this equation;

Pw; represents the soil water content based on weight (mass),

YA; represents the wet weight of the soil sample,
KA; represents the dry weight of the sample.
According to this equation, the amount of water contained in the soil mass/gram is determined in mass/gram (Kırda and Sarıyev, 2002).
The working principle of the TDR method was identified as follows (Topp et al., 1980; Jones et al, 2002);

$$\varepsilon = \left(\frac{ct}{2L}\right)^2$$

Here:
ε represents dielectric constant,
c represents the velocity of light in space ($3x10^8$ ms^{-1}),
t represents the travel time of the pulse within the media,
L represents the length of the electrode.
As can be understood from the formula above, the basic principle of the measurement is explained through the change in the soil dielectric constant (ε) depending on the soil water content. The relationship between the dielectric constant and volumetric water content is determined as (θ=f[ε]; 3^{rd} degree polynomial).

RESULTS AND DISCUSSIONS

Advantages and disadvantages of the gravimetric method

The findings of this study drew similarities to the study conducted by Zazueta and Xin 1994 in terms of the advantages and disadvantages of the gravimetric method. As a direct measurement method, the gravimetric method has advantages in that it measures accurately, is not affected by the soil type and salinity and is easily calculable.
The most significant disadvantage of the method is that it requires the soil sample to be kept for 1 full day until it is dried out completely at 105^oC degrees and before it weighed, and thus taking nearly 2 days to determine the humidity content of the soil sample in addition to the time elapsed in collecting the soil samples.
Moreover, the labor required in gathering the 54 soil samples from 18 different parcels before and after the irrigation and for control purposes was also found to be significantly costly.
Another disadvantage of the gravimetric method is the increase in the number of macro gaps resulting collecting soil samples. Such gaps are highly important in terms of being replaced, depending on the agricultural awareness of the worker taking the soil sample, preserving the soil structure and avoiding soil loss.

Advantages and disadvantages of the TDR (Time Domain Reflectometry) method

This method was tried out by various researches in different soil textures, and the equipment was found to be conveniently usable in determining the humidity content of the soil. The advantages of the TDR equipment include less destruction of the macropores in the soil compared to the gravimetric method, easier transportation in the field, saving time and labor costs, allowing measurements at the required depths thanks to convenient handling of the equipment by the farmer and easier determination of the water requirement of the plants. One of the major advantages of the TDR equipment over the gravimetric method is that the water content of the soil is calculated instantly without having to wait for 24 hours as in the case of gravimetric method.
In addition to being costlier than the gravimetric method, the disadvantage of the system includes the necessity to prepare different calibration curves for different soil textures. Moreover, the increase in the percentage of clay and organic substances in the soil also contribute to the errors in the measurements performed by the TDR equipment.
As a result of this study, the advantages and disadvantages of the TDR method were found to be similar to those found by various other researchers (Zazueta ve Xin., 1994; Irmak et al., 1999; Tanrıverdi, 2005; Tülün, 2005; Küp, 2009).

Determining the calibration curve

Although the gravimetric method has negative aspects in terms of time and labor costs as compared to the TDR method, the method applied in TDR calibration is a standard one as in the case of all indirect methods. For this reason, in order to achieve more reliable results in the TDR method, the TDR calibration of the gravimetric method should also be used as well (Tanrıverdi, 2005; Uytun et al., 2013; Zhou et al., 2014; Capar and Ucan, 2015). In this study, the values measured in the 15, 45 and 70 cm deep soil layers through gravimetric and TDR methods are represented in the Figures 1, 2 and 3 below.

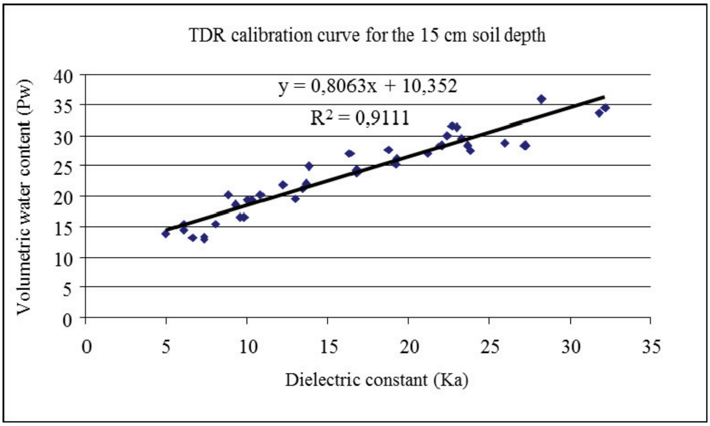

Figure 1. TDR calibration curve for the 15 cm soil depth

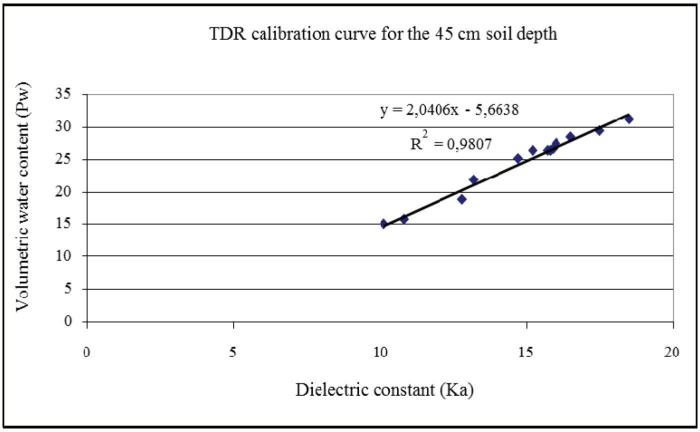

Figure 2. TDR calibration curve for the 45 cm soil depth

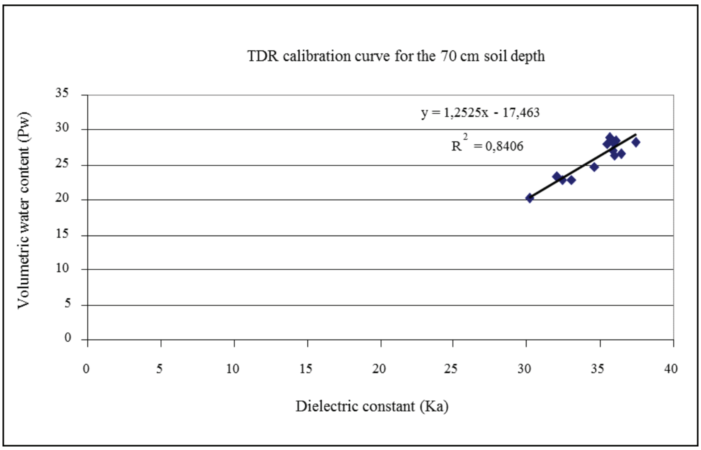

Figure 3. TDR calibration curve for the 70 cm soil depth

The fact that the correlation coefficient between the volumetric water content and dielectric constant was found to be higher in this study suggests that the TDR equipment can be very easily used for these kinds of soils.

As a result of the statistical analysis, the relationship between the gravimetric method and the TDR measurements were found to be significant ($p<0.05$). The result of the analysis suggested that there was a strong relationship between the measurements and that the findings of the present study bore similarities to the studies conducted by Tanrıverdi, 2005; Tülün, 2005; Küp, 2009.

Saving labor costs

The amount of time spent in collecting samples in 15, 45 and 70 cm deep soil in gravimetric method takes no longer than 5 minutes. This length of time is also related to the experience on the part of the person collecting the sample, the likelihood of hitting the hand brace to a stone in the underground, the time spent in wrapping up the lids of the sample containers in an effort to avoid the evaporation of the moisture of the soil sample therein, which contribute to the extension of the overall measurement time. In the TDR method, however, the measurements take about 1 minute for the 3 soil depths.

Since the amount of labor spent in the study cannot be included in the units of measurements, it was measured by way of verbal dialogs. According to the verbal dialogs, the difference between the gravimetric method and the TDR measurement methods were considerably big. As a result of the statistical analysis, the difference between the measurements performed by the gravimetric measurement and TDR equipment were found to be statistically very significant ($p<0.01$).

CONCLUSION

The studies that aim to preserve our domestic soil and water resources are conducted on a continuous basis by all the national institutions, yet they fail to relate to the level of the Turkish farmer. Although the studies thus far conducted with a view to extending the agricultural technological developments in our country and yielding more crops from a unit area are found to be encouraging, it is our view that the failure of such studies to relate to the level of the farmer is one of the major reasons why the efficiency in agricultural terms has not yet lived up to the expectations.

In this study where the direct and indirect measurement methods have been compared in order to determine the amount of water to be provided to the plants by the farmers on a timely basis so as to avoid the plant going through water stress;

It was established that the gravimetric measurement method despite being time consuming and costly in terms of labor- was essential, as a direct measurement method, in terms of calibrating the indirect methods.

On the other hand, the TDR measurement method, as an indirect measurement method, was found to have a number of advantages, in addition to saving time and labor costs, such as

- Enabling direct measurement in the field,
- Being mobile, lightweight and easily transportable,
- Capable of being used in different soil textures,
- Reducing the number of macropores in the soil,
- But it was also found to have a drawback in that extreme care should be taken when used in soils with high percentages of clay and organic substances.

As suggested by a number of researchers, the use of calibrated TDR will make significant contributions to the domestic farmer in terms of efficiency, time and labor cost saving thanks to it’s a for ementioned advantages (Irmak et. al., 1999; Tanrıverdi, 2005; Küp, 2009; Quaknin et. al., 2015; Satriani et. al., 2015; Chung et. al., 2016).

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