CALIBRATION OF TIME DOMAIN REFLECTOMETRY (TDR) SOIL MOISTURE POINT PROBE FOR TWO SOILS

Maqsood Ahmed Khan[1], Ehsanullah Kakar[2], Dost Mohammad Baloch[3], Salah Ud Din Azad[1]

[1]Department of Environmental Management & Policy, [2]Department of Civil Engineering, [3]Department of Biotechnology & Informatics, Balochistan University of Information Technology, Engineering & Management Sciences Quetta

Abstract

Maintaining adequate soil moisture in the root zone is crucial in achieving good plant growth. Accurate measurement of soil moisture is essential to keep the right level of soil moisture. Many studies have reported the successful application of Time Domain Reflectometry (TDR) for soil moisture measurement. This study was initiated to obtain calibration curves for soil water content determinations by TDR for two soil types.

Measurements were taken in the laboratory for a silt loam and a sandy loam soils, using TDR Soil Moisture Measurement Instrument, Moisture Point™ Model MP-917, and Moisture Point Probe type-K. TDR probe calibration was performed for two soil types contained in wooden boxes (100 cm x 100 cm x 80 cm). The calibration was accomplished by comparing the volumetric moisture content (θ_{TDR}) and time delay (τ_{TDR}) response of TDR probe to that of the gravimetric volumetric moisture content (θ_{grav}). The TDR measurements were taken, in triplicates, at four depths (0-15 cm, 15-30 cm, 30-45 cm, and 45-60 cm) for 38 days after wetting the soil. Soil samples for the gravimetric moisture content measurements were collected from the same locations from where TDR readings were taken.

The study has demonstrated that the TDR technique is a reliable alternative method for measuring soil moisture content. The moisture content measurements obtained with TDR were comparable to that of the gravimetric method and showed a good relationship to gravimetric determinations (r^2=0.85 for silt loam and 0.89 for sandy loam).

KEY WORDS:
Calibration, Time Domain Reflectometry (TDR), Soil Moisture, Root zone, Time Delay

INTRODUCTION

As early as 1939, geologists and others recognized a relationship between the dielectric properties of soil, rock and other materials, and their moisture content. However, they lacked the instrumentation necessary to make full use of it.

Time Domain Reflectometry, commonly known as TDR, largely developed as the result of World War II radar research, offered a method to define these dielectric relationships. With the advent of commercial TDR research oscilloscopes in the early 1960's, it became feasible to test this new technology. Today, TDR technology is the cutting edge methodology for many diverse applications including the determination of basic soil water. The practical interest stems from the fact that dry soil has a dielectric constant range of 2 to 4 compared to values of 78 to 81 for water. Therefore, the dielectric properties provide an excellent measure of the water content of soil (Selig and Mansukhani, 1976). Topp et al. (1980) placed different type of soils and soil like materials around coaxial transmission lines with 5 cm spacing and 100 or 30 cm length and found that the dielectric constant was only affected by water content.

Many studies have reported that application of TDR to soil measurement has been successful. It has become an acceptable method for non-destructive estimation of soil water content. TDR converts the travel time of a high frequency, electromagnetic pulse into volumetric water content. In practice it generates a fast-rise pulse and sends it at the speed of light down a transmission line consisting of two parallel Waveguides (probe) that are inserted or buried in the soil. The velocity of propagation of the high frequency, broad band 3GHz wave in soil is determined primarily by the water content. The wave is reflected from the open ends of the Waveguides (probe) and returns along the original path. By microprocessor, the travel time of the wave is used to directly calculate the dielectric constant of the soil. The actual time delay and correlated volumetric water content are also digitally displayed on screen.

Moisture Point uses the latest technology of instrumentation specifically designed to give research scientists, commercial growers, and consultants the power and flexibility to measure and log water relationships of soils and other materials by fast, accurate, easy to use TDR methods. The convenient full featured push button ease of use, direct reading of actual Time Delay and Volumetric Moisture Content, is made possible by this model.

TDR Moisture Point has been engineered to meet current and future needs, and has the capability to accept new software and hardware offered by Soil moisture.

TDR eliminates the need for using nuclear based instrumentation and the associated radiation, health and safety hazards. It eliminates site specific calibration and the requirement for costly, specialized licensed personnel associated with neutron probes. It also provides auto-logging capabilities not practical with nuclear techniques.

Dasberg and Dalton (1985), found that the water content measurements obtained with TDR showed a good relationship to gravimetric determinations and were also comparable to neutron probe measurements. Topp and Davis (1985), compared the water content measurements obtained with TDR and gravimetric methods, and it showed that generally both were the same values.

Although application of TDR has been successful in many reported studies, question still arises with regard to the versatility of the method when used among different textured soils.
The purpose of the study was to compare the soil moisture content measurements carried out by TDR and gravimetric method for two different soil types and to obtain calibration curves for soil water content determinations by TDR.

MATERIALS AND METHODS

Measurements were taken for a silt loam and a sandy loam soils, using TDR Soil Moisture Measurement Instrument, Moisture Point^{TM} Model MP-917, and Moisture Point Probe type-K.

Calibration was performed for the soils in the wooden box (100 cm x 100 cm x 80 cm) for probe to be used for data collection (Figure 1). The composition of soils used in the study in given in table 1. The calibration was accomplished by comparing the TDR readings (both Vol. MC and Time Delay) to those of the Gravimetric Volumetric Water Content (Tables 2 & 3). For this purpose, three soil samples from each depth were collected from the box immediately after the TDR readings at the exact location at four depths (0-15 cm, 15-30 cm, 30-45 cm, and 45-60 cm) at different intervals for 38 days after wetting of soil. All determinations were made in triplicates and the average values were used.

Along with taking the TDR readings (MC and Time Delay), the volumetric water content was calculated by weighing wet and an oven dried samples for each soil depth. Volumetric water content (gravimetric) versus Volumetric water content (TDR) and Time Delay data was ready to be used to fit an appropriate regression equation.

RESULTS AND DISCUSSION

The average volumetric water contents measured with TDR, and obtained by gravimetrically from actual soil samples along with the TDR Time Delay readings for silt loam and sandy loam are given in Tables 2 and 3 respectively.

Figures 2 and 3 show the relationships between gravimetrically determined volumetric water contents and TDR measurements; the gravimetric water content Vs TDR Time Delay; and TDR water content Vs Time Delay measurements for silt loam and sandy loam soils.

Soil Type	Clay (%)	Silt (%)	Sand (%)	Bulk Density (g/cm^3)	Field Capacity (%)
Silt Loam	21	63	16	1.24	49
Sandy Loam	10.5	31.5	58	1.35	25

Table 1. Composition and properties of soils used in the study.

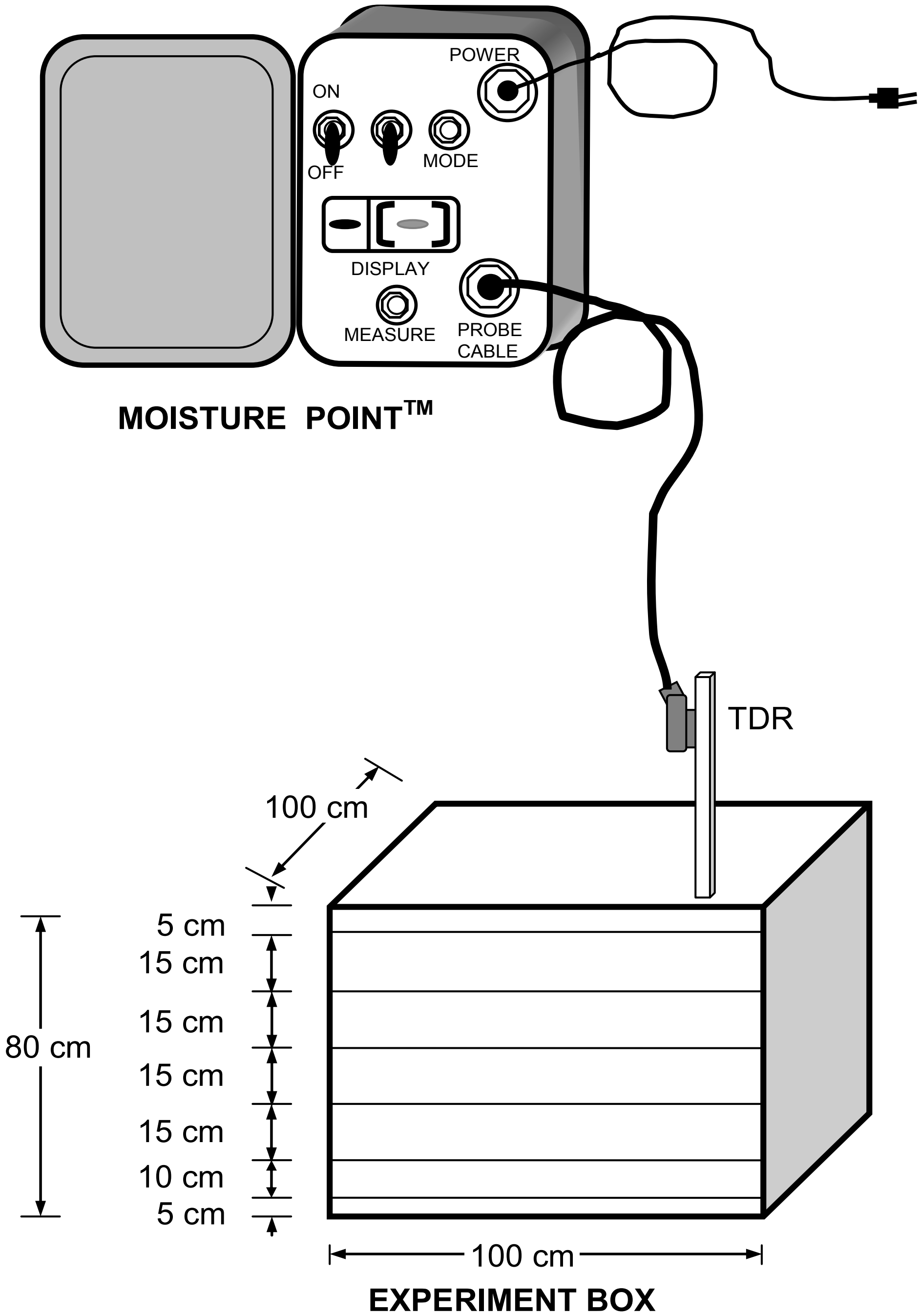


Figure 1. Experimental setup for TDR Moisture Point Calibration.

The calculated regression equations and coefficients of determination (r^2) are also included in the plots and are as below:

for silt loam soil,

$$\theta_{grav} = 1.20060\theta_{TDR} - 1.8981 \quad r^2 = 0.85 \quad (1)$$

$$\theta_{grav} = 23.02\tau_{TDR} - 39.125 \quad r^2 = 0.85 \quad (2)$$

$$\theta_{TDR} = 19.103\tau_{TDR} - 30.755 \quad r^2 = 0.99 \quad (3)$$

and for sandy loam soil,

$$\theta_{grav} = 1.92410\theta_{TDR} - 18.658 \quad r^2 = 0.89 \quad (4)$$

$$\theta_{grav} = 31.308\tau_{TDR} - 63.523 \quad r^2 = 0.86 \quad (5)$$

$$\theta_{TDR} = 16.379\tau_{TDR} - 23.615 \quad r^2 = 0.99 \quad (6)$$

These data show satisfactory close correlation between TDR and gravimetrically determined water content measurements. The lower correlation coefficient between θ_{grav} and θ_{TDR}

may be due to spatial variability in the horizontal and vertical planes containing the sampling and measuring volumes. In addition to this the human error can also be a factor.

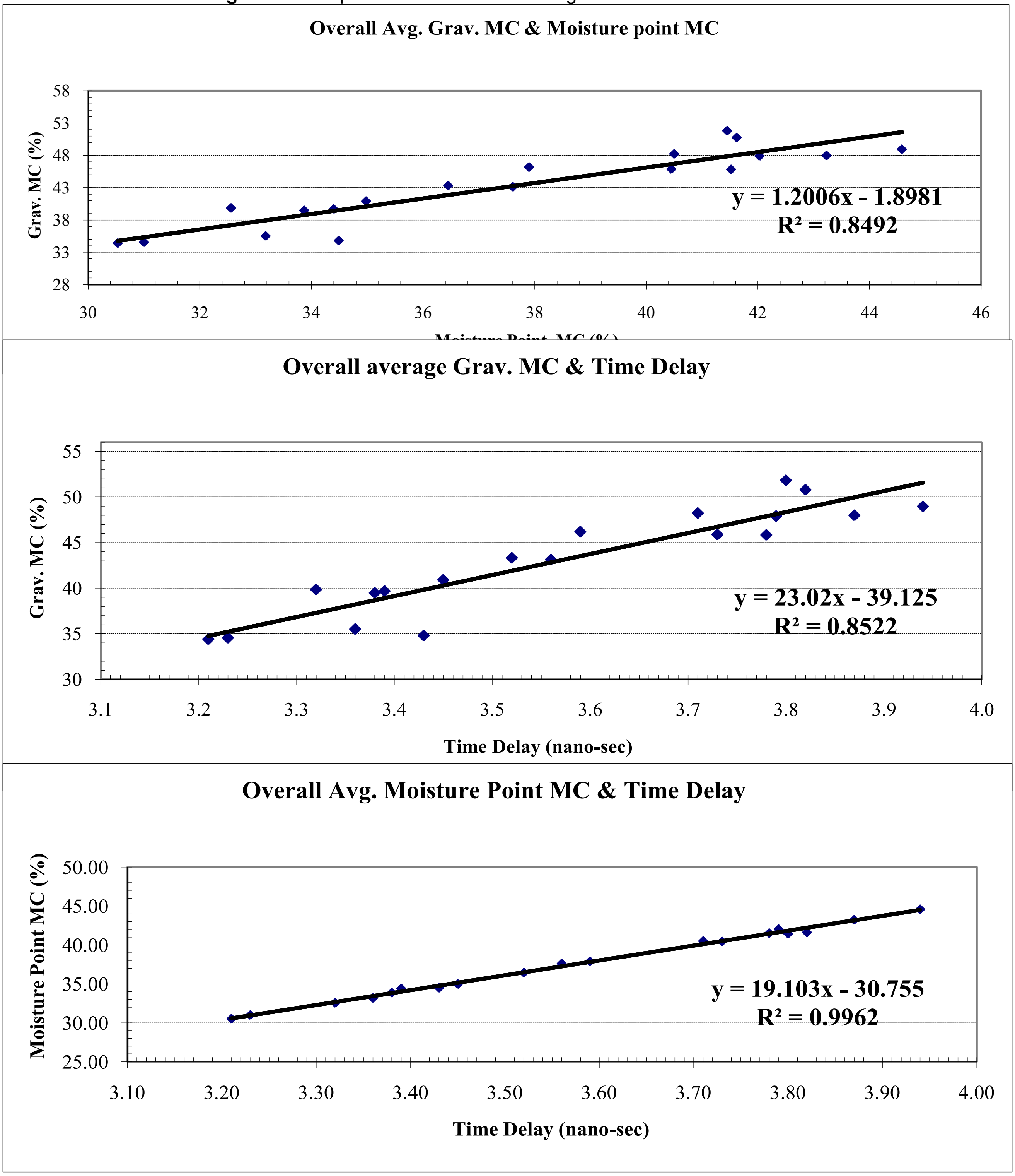
Days After Wetting	Gravimetric Vol. M.C. (%) *(M.C.%*Bulk Density)*	Moisture Point Probe Readings	
		M.C. (%)	Time Delay (nano-sec)
1	51.82	41.45	3.80
2	50.78	41.62	3.82
3	48.96	44.58	3.94
5	45.88	40.45	3.73
6	48.23	40.50	3.71
8	45.83	41.52	3.78
9	47.98	43.23	3.87
10	47.90	42.03	3.79
15	46.19	37.90	3.59
16	43.13	37.61	3.56
17	43.32	36.45	3.52
18	40.91	34.98	3.45
19	39.85	32.56	3.32
23	39.48	33.87	3.38
25	39.68	34.40	3.39
26	34.80	34.49	3.43
28	35.51	33.18	3.36
32	34.40	30.53	3.21
38	34.55	31.00	3.23

Table 2. Average Moisture Contents and Time Delay for Silt Loam.

Days After Wetting	Gravimetric Vol. M.C. (%) *(M.C.%*Bulk Density)*	Moisture Point Probe Readings	
		MC *(%)*	Time Delay *(nano-sec)*
0	36.90	28.44	3.19
2	25.91	21.61	2.73
3	24.69	23.41	2.84
4	22.42	21.31	2.74
5	22.04	22.08	2.79
6	22.56	20.55	2.70
7	21.31	20.90	2.72
8	20.87	19.45	2.64
9	19.61	20.63	2.69
10	19.79	20.87	2.74
12	18.17	19.57	2.66

Table 3. Average Moisture Contents and Time Delay for sandy loam.

Figure 2. Comparison between TDR and gravimetric data for silt loam soil.



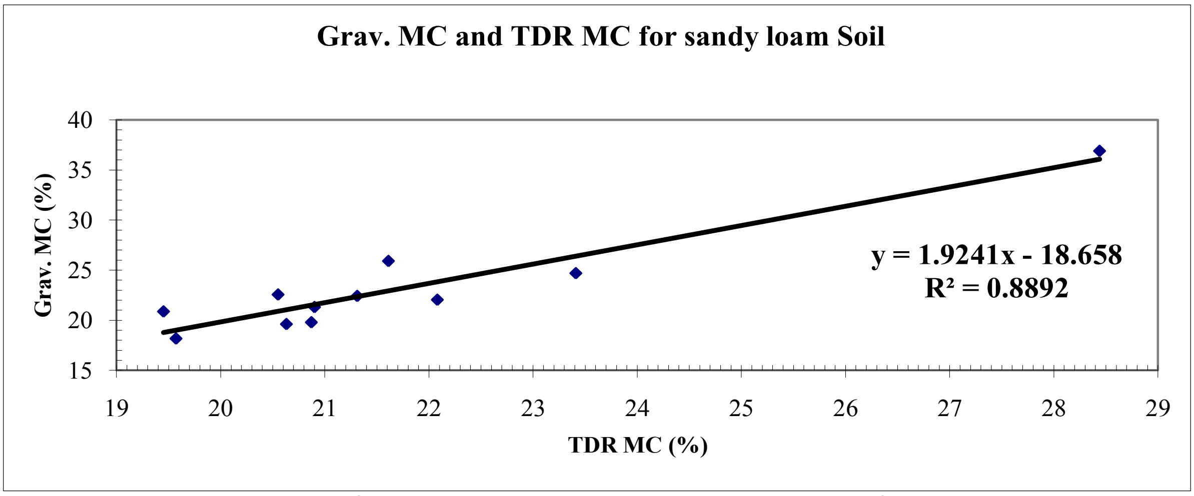
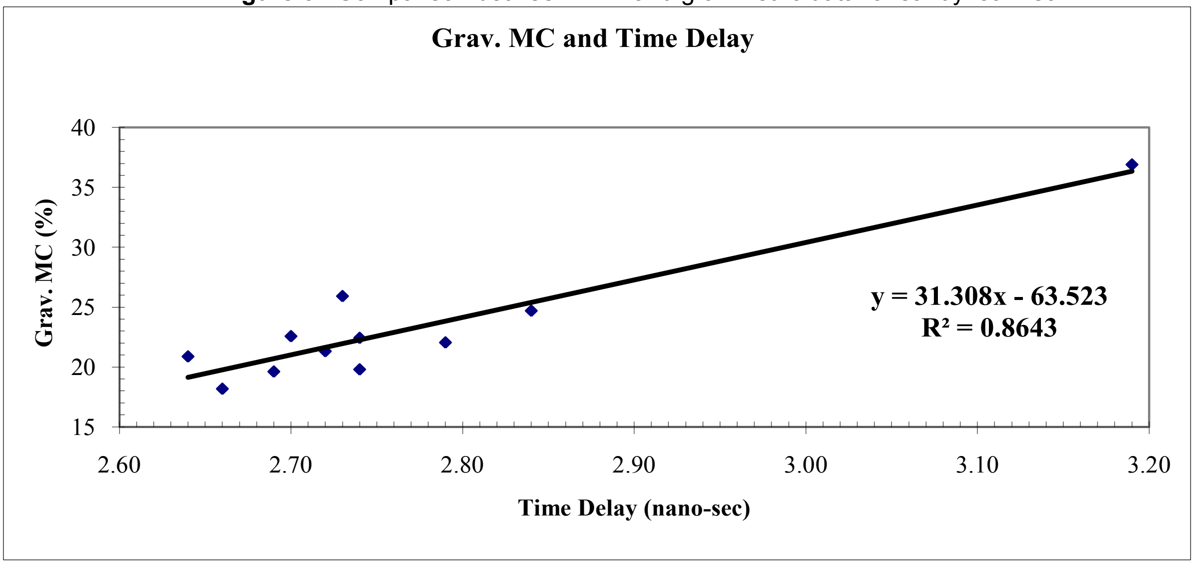
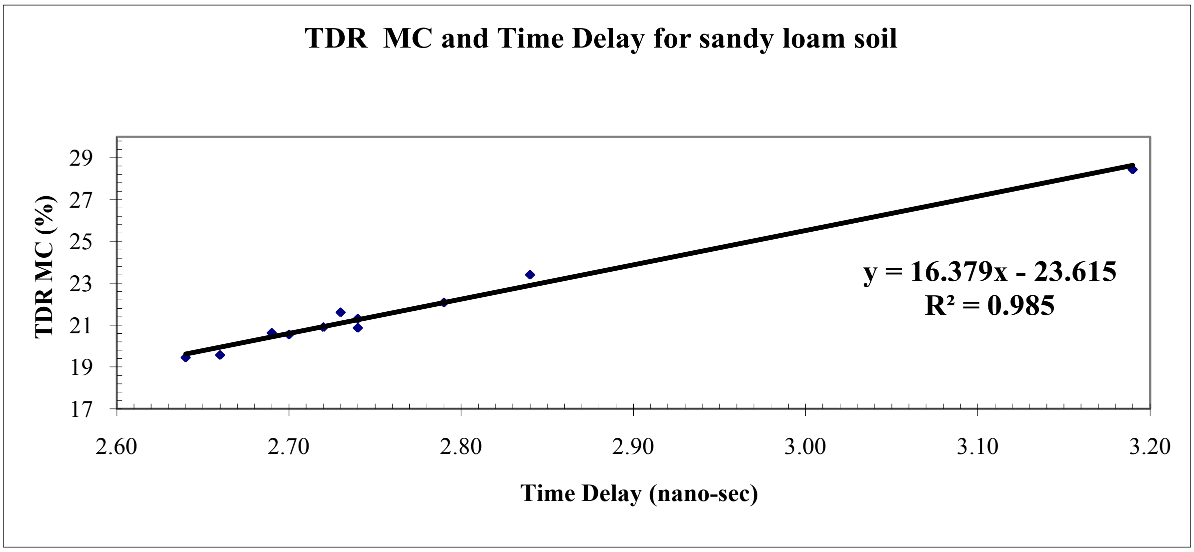


Figure 3. Comparison between TDR and gravimetric data for sandy loam soil.





CONCLUSIONS

The calibration study has demonstrated that the TDR technique for the measurement of soil water content is very close to gravimetric method. Therefore it can be used to estimate the volumetric water content in soils used in research studies.

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