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Soil Moisture Estimation using Gravimetric Technique and FDR Probe Technique: A Comparative Analysis

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Abstract*: Soil-Moisture is generally defined as the water held in the spaces among the soil particles. Surface soil-moisture is the water that is within the upper 10cm of soil, while the root zone soil-moisture is the water available to plants, generally considered to be in the upper 50-to-200cm of soil.(GHCC-NASA). Soil-moisture is of fundamental importance to many hydrological and biological processes and thus soil-moisture information is valuable to many researchers worldwide for studies related to weather and climate, runoff potential and flood control, Geotechnical engineering etc. soil-moisture plays an important role in the development of weather patterns. Soil-moisture information can be used for reservoir management, early warning of droughts, irrigation scheduling and crop yield forecasting. While remote sensing of soil moisture using microwave remote sensing technique is well established, one of the critical step is to calibrate and validate the soil moisture derived using remote sensing methods. This calls for measuring the soil moisture for a few locations on the ground in synchrony with the satellite pass. While gravimetric method is practiced for measuring field soil moisture,* it *is time consuming, soil moisture measured using probes is much faster. This paper offers a comparative analysis on soil moisture measured by gravimetric technique and soil-moisture estimation using FDR (Frequency Domain Radiometry) probe methods over different study areas.*

Key Words*: Soil-Moisture, runoff potential, Flood control, Frequency Domain Radiometry, crop yield forecasting*

I. Introduction

Soil moisture is one of the most important parameters governing meteorological, hydrological, agricultural and climate related events. Thus, it is very important to have the information regarding soil moisture and its spatial and temporal variations. Such information can be very useful to a wide range of government agencies and private companies concerned with weather and climate, flood control, crop yielding estimation, reservoir management, geotechnical engineering and water quality etc. Soil moisture is highly dynamic in nature both spatially and temporally. Hence, it is very difficult to collect soil moisture information using ground based measurement over a wide area. Such measurements are also tedious and time consuming. Remote sensing offers a very good alternative to these measurements as it provides information over a large area and offers a practical, timely and cost effective means for soil moisture estimation. In particular microwave remote sensing has the highest potential for remotely sensing soil moisture among the various electromagnetic bands. The key factor behind it is the large difference in dielectric constant between water (~80) and dry soil (3to4) at microwave frequencies. Techniques using microwave remote sensing for soil moisture estimation are well established and practised for some time now, one of the important step in this process is to calibrate and validate the soil moisture derived using these techniques. To achieve this, soil moisture is needed to be measured from few locations on the ground synchronous to the satellite pass. Most commonly used technique for this is gravimetric technique. But it is time consuming and a bit less accurate compared to the soil moisture estimation probes. Measurements using probes are much faster. There are several types of soil moisture estimation probes available like Frequency Domain Reflectometry (FDR), Time Domain Reflectometry (TDR) and Neutron Moisture Gauge. Cheap sensors, often for home use, are based on two electrodes measuring the resistance of soil. Frequency Domain Reflectometry (FDR) sensor has an oscillating circuit and sensing part of the sensor is embedded in the soil. FDR sensor uses either capacitance or electrical impedance to measure soil moisture. Time Domain Reflectrometry (TDR) sensor measures the dielectric constant of a soil in order to measure soil moisture. Neutron Moisture Gauge utilizes the moderator properties of water to measure soil moisture.

II. Materials and Methodology

Two types of soil moisture estimation techniques were used for this comparison study.

1. Gravimetric Technique.
2. Frequency Domain Reflectometry (FDR) Sensor.

A. Gravimetric Technique for Soil Moisture Estimation

The soil moisture content may be expressed in terms of weight as the ratio of weight difference between wet and dry soil to the weight of dry soil orin terms of volume as ratio of volume of water to the total volume of the soil sample.In order to find out any of these ratios, weight of the water in a soil sample must be determined by drying the soil sample to a constant weight and measuring the wet and dry mass of the soil sample before and after drying. Weight of the water present in the soil sample is the weight difference between wet and oven dry soil sample. The criteria for oven drying a sample is to dry the soil sample to a constant weight in the oven between the temperature range of 100°C - 110°C.

III. Materials

- Oven with 100°C –110°C temperature.
- A balance of precision of ±0.001 g.
- Auger or tool to collect soil samples.
- Soil Moisture boxes.

IV. Procedure

Soil samples were collected from the depth of 5 and 10 cm in the soil moisture boxes. These boxes were weighed using digital weighing machine and their initial weights were noted down. The samples were brought to the laboratory and put in the oven for 24 hours at 105°C. Once the oven drying was complete the samples were weighed again and their weights were noted down. These are the weights after oven drying. After oven drying, the empty weights of soil moisture boxes were measured.

V. Computations

The moisture content in dry weight basis may be calculated using the following formula:

$$m_d = \frac{(wt\ of\ wet\ soil\ tare) - (wt\ of\ dry\ soil\ tare)}{(wt\ of\ dry\ soil\ tare) - (tare)}$$

Water content in volumetric basis is expressed as:

$$m_{vd} = \frac{Volume\ of\ soil}{Volume\ of\ water}$$

But

$$Volume\ of\ water = \frac{wt\ of\ water}{water\ density}$$

And:

$$Volume\ of\ soil = \frac{bulk\ density}{wt\ of\ dry\ soil}$$

Thus:

$$m_{vd} = \frac{wt\ of\ water}{wt\ of\ dry\ soil} \times \frac{bulk\ density}{water\ density}$$

B. FDR Probe Technique for soil Moisture Measurement

The FDR has an oscillatory circuit and the sensing part of the sensor is attached at the end of the probe. In order to take the measurements, a PVC pipe is to be installed first in the soil. Then, the probe is inserted into the pipe and gives measurements at an interval of 10 cm. Generally such probes can measure soil moisture up to 1 m in the soil. The data is saved in the data logger connected to the probe.

Materials

- FDR Probe
- Data Logger
- PVC Pipes
- Power Auger

Procedure

In order to install the PVC pipe into the ground, a small area from where the soil moisture reading was to be taken was dug using power auger. After that the PVC pipe was installed in the area and a rubber block was inserted into the pipe.Data logger was connected to the FDR probe and the probe was inserted in to the pipe up to the full extent and then was brought out of the pipe in order to complete the reading procedure. The data had been stored in the data logger connected with FDR probe.

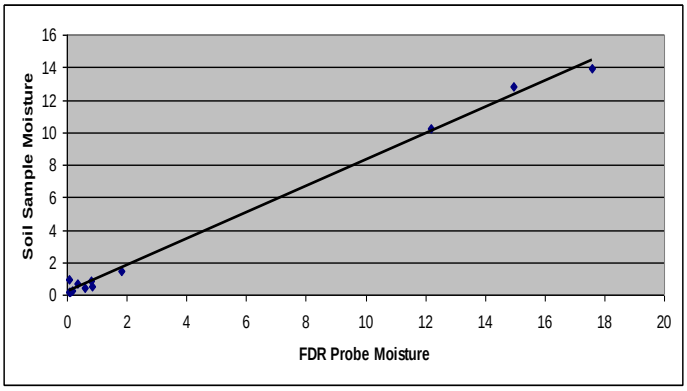
VI. Results and Discussion

From FDR probe soil moisture from 5cm, 10 cm and 30 cm has been measured on the field, however the soil moisture samples were not feasible to be taken from such depth with accuracy. So soil moisture samples from only 10 cm have been included for this study. Total 13 soil sampling locations in India have been selected which cover Kutch, Jodhpur, Bharatpur and Roorkee in the month of February and March.

Table 1: FDR probe soil moisture from 5cm, 10cm and 30cm measured on the field and correlation coefficient.

Sr No.	Soil Moisture		Correlation Coefficient
	FDR probe	Gravimetric	
1	0.16	0.13	0.998977368
2	0.33	0.38	
3	0.57	0.61	
4	0.22	0.45	
5	0.89	0.65	
6	0.93	0.88	
7	0.76	0.71	
8	1.56	1.23	
9	1.12	1.06	
10	1.89	1.77	
11	12.23	10.37	
12	15.52	13.16	
13	17.89	14.13	

Figure 1: Graphical representation of Soil Sample Moisture vs. FDR Probe Moisture



A comparison of FDR moisture values and soil sample moisture values was made and it was seen that there is a very high correlation between FDR moisture values and soil sample moisture values estimated in the lab. The Correlation Coefficient turned out to be 0.998977. In figure above a relation is being shown between the FDR probe moisture values and the soil sample measured values. On X axis FDR moisture values are plotted and on the Y axis soil sample moisture values are plotted. It can be seen that a very good relation is established between both the two values. Hence this study shows that FDR probe moisture values can be used for soil moisture-measurements.

References

1. "Large area soil moisture estimation using multi-incidence angle Radarsat-1 SAR data" (2009), H. S. Srivastava, Parul Patel, Y. Sharma and Rangnath R. Navalgund, *IEEE transactions on geosciences and Remote sensing*, Vol. 47, No. 8, pp.2528-2535.
2. Kurt C. Kornelsen a, PaulinCoulibaly, Advances in soil moisture retrieval from synthetic aperture radar and hydrological applications, 2013, Journal of Hydrology 476 (2013) 460-489
3. "How far SAR has fulfilled its expectation for soil moisture retrieval", (2006), H. S. Srivastava, Parul Patel, Rangnath R Navalgund, Proceedings of 5th international symposium on Asia-Pacific Remote Sensing-2006, organized by International society for optical Engineering (SPIE) held at Goa during 13-16 Nov-2006, *SPIE Digital Library* Vol. 6410, Paper Number: 641001, pp. 01-12.
4. Black C.A. 1965. "Methods of Soil Analysis: Part I Physical and mineralogical properties". *American Society of Agronomy, Madison, Wisconsin, USA.*
5. Global Hydrology and Climate Center- NASA.

6. ASTM D 2216 - Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures.
7. T. William Lambe& Robert V. Whitman (1969). "Chapter 3: Description of an Assemblage of Particles". *Soil Mechanics* (First ed.). John Wiley & Sons, Inc. p. 553. ISBN 0-471-51192-7
8. F. Ozcep, M. Asci, O. Tezel, T. Yas, N. Alpaslan, D. Gundogdu (2005). "Relationships between Electrical Properties (in Situ) and Water Content (in the Laboratory) of Some Soils in Turkey". *Geophysical Research Abstracts* 7.