Development of Relationship between Soil Moisture Depletion and Leaf Area Index of Different Horticultural Crops

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Abstract

A relationship between soil moisture depletion and leaf area index (LAI) of mango and brinjal was developed at IGKV, Raipur. A Permanent Profile Soil Moisture Probe was validated for 60 cm depth having 15 cm interval using gravimetric method. Soil properties such as FC, infiltration rate, pH, EC, OC, P and K were analyzed. The values of r^2 for the four depths were found to be 0.957, 0.950, 0.954 and 0.895 whereas RMSE values were found to be 1.622, 1.108, 0.857 and 1.051, respectively. A Plant Canopy Analyzer was used to analyze LAI of mango and brinjal for developing the relationships between moisture depletion and LAI. Values of LAI of mango and brinjal found to be 3.29-4.46 and 3.99, respectively. Moisture depletion values of ranged between 7.20-15.81 %, 7.39-11.88 %, 10.59-14.02 % and 19.90-22.66 % for mango with brinjal for 4 depths whereas 7.26-15.13 % and 7.75-16.76 % of mango for 2 depths, respectively.

Keywords: Gravimetric Method, LAI, Moisture Depletion, Permanent Profile Soil Moisture Probe, Plant Canopy Analyzer, Soil Properties, Validation.

Introduction

Soil moisture is vital in tree growth and fruit development phases because it is required to maintain the optimum moisture regime within the rhizosphere. It substantially impacts plant development, percolation, evaporation, microbiological decomposition of organic matter in the soil, and heat exchange. Soil moisture information is critical for various applications such as irrigation scheduling, plant stress and crop yield improvement. As a result, accurate soil moisture estimates are critical in several applications, such as examining the effect of climate change on land surface hydrological variables such as soil moisture, infiltration fluxes, runoff and surface temperature caused by changes in heat fluxes and quantifying the amount and seasonal variability of regional water resources in water-stressed regions of the world.

Soil moisture estimation has been well established and practiced for some time now; one crucial stage in this process is to validate the soil moisture estimated using these methodologies. Soil moisture must be measured from a few locations on the ground to do this. In recent decades, various methods for estimating soil moisture content have been available, which can be classified into classical and current procedures for both laboratory and in situ measurements. Traditional soil moisture measurement is extracting moisture from a soil sample through evaporation or a chemical reaction that includes thermo-

gravimetric and calcium carbide procedures. The gravimetric method is the most often used technique for this. However, it takes more time and laborious.
Soil moisture sensors measures the soil moisture content and proved to be an aid for better irrigation management. Good irrigation management gives better crops, uses fewer inputs and increases profitability. Soil moisture sensors help irrigators to understand what is happening in the root zone. The validation of soil moisture data sets aims to provide quantitative information about their quality. Probe measurements are considerably faster. Soil moisture estimate probes include Frequency Domain Reflectometry (FDR), Time Domain Reflectometry (TDR) and Neutron Moisture Gauge. Cheap sensors, often for household use, are based on two electrodes that measure soil resistance (Shukla *et al.*, 2014). This study offers a comparative analysis of soil moisture measured by gravimetric method and soil moisture estimation using the Permanent Profile Soil moisture probe method.
The leaf area index (LAI) is a vital physiological feature that can be used toassess the performance of a plant canopy in terms of growth and yield (Roth *et al.*2018).The LAI maps derived from MERIS and ASAR data may be efficiently assimilated into the CERES-Wheat model, resulting in yield map accuracies ranging from 360 kg/ha to 420 kg/ha (Dente *et al.* 2007). The digital cameras can be utilized toassess crop LAI in an inexpensive and straightforward manner (Tavakoli 2017). The optimal irrigation strategy for eggplant could depend on balancing the situational requirements in terms of irrigation water, yields, and fruit size and quality (Kirnak *et al.* 2002). Plant canopy volume, LAI, and yield were discovered to be connected during the experiment. Mango tree yield shows an increasing tendency as plant canopy volume and LAI increase (Samant *et al.* 2020).
Looking the importance of soil moisture sensors plant canopy analyzer a study was conducted at the Indira Gandhi Krishi Vishwavidyalaya (IGKV), Raipur in Chhattisgarh. Experimental sites were categorized as Field-A and Field-B. The relationship between soil moisture depletion and leaf area index of different horticulture crops has been developed in this study. In order to achieve set target physio-chemical properties of soil of the study area were determined then soil moisture measured using Permanent Profile Soil Moisture Probe at different depths was validated using standard gravimetric method of moisture measurement. Soil samples were collected manually and analyzed for physical and chemical properties in the department of Soil Science and Agricultural Chemistry, IGKV, Raipur. Furthermore, relationship between soil moisture depletion and LAI for mango and brinjal was developed in this study.

Materials and Methods

The research work was carried out in the horticulture field of Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). A Permanent Profile Soil Moisture Probe was installed at the mango orchard in the horticulture field. The experimental field is located in front of Horticulture Nursery at 21°14′3′′ N and 81°42′43′′ E and with an altitude of 292 m above the mean sea level. Raipur district is located under the agro-climatic zone “Chhattisgarh Plains” in the state of Chhattisgarh. Soil samples were collected manually at the regular periodicity of 15 days from the field at various depths up to 60 cm using an auger and core sampler and soil moisture data will be calculated by the gravimetric method in the laboratory of the Department of Soil and Water Engineering of IGKV, Raipur.

Gravimetric Method for Soil Moisture Measurement

Basically, the gravimetric method involves taking a soil sample, weighing, oven drying and reweighing it, then expressing the moisture content (i.e. the loss in weight) as a percentage of the oven dry weight of soil. This is the weight or mass basis of expressing soil moisture content. Alternatively, by multiplying by the bulk density, the results may be expressed on a volume basis.The criteria for oven drying samples were to first dry the soil sample to a constant weight in the oven between the temperature ranges of 105°C for 24 hours. The moisture content was calculated using the following formula on a dry weight basis.

$$Md = \frac{Weight\ of\ wet\ soil - Weight\ of\ dry\ soil}{Weight\ of\ dry\ soil} \times 100 \qquad \ldots(1)$$

where,

Md is Soil moisture content on dry basis (%)

$$VWC = Md \times Bd \qquad \ldots(2)$$

where,

VWC is Volumetric water content or Volumetric soil moisture content in % and Bd is Bulk density (g/cm^3)

Permanent Profile Soil Moisture Probe

A Permanent profile soil moisture probe was installed in the horticulture field of IGKV, Raipur (C.G.) funded by the National Remote Sensing Centre (NRSC) under the National Hydrology Project (NHP). This sensor measures the soil moisture at 6 different depths up to 90 cm from ground level at an interval of 15 cm. This sensor records data in the form of volumetric water content (%) and stores data in the data logger with a connection of solar power source.

Plant Canopy Analyzer

Leaf Area Index (LAI) is the ratio of one-sided leaf area per unit ground area. LAI is unit less because it is a ratio of areas. The measurement of leaf area is one of the most essential parameters in agricultural research, particularly in plant physiology and nutrition. Measuring LAI used to be complicated and time-consuming. However, recent advances in theory and technology have made measuring LAI simpler and more viable for a wide range of canopies. The LAI 2200C Plant Canopy Analyzer is a device/non-destructive methodto easily and accurately measure LAI.

Results and Discussion

In this study, two moisture determination methods were compared in which both direct and indirect methods were used. In the direct method, a standard gravimetric method and a permanent profile soil moisture probe *i.e.* indirect method was used. For comparison and validation of the soil moisture probe, the gravimetric moisture content determination method (oven drying method) was used and estimated the moisture content during the study period at the interval of 15 days or twice a month from January 23, 2022 to June 23, 2022. Compression of moisture content (%) measured using Profile probe and gravimetric method in 4 depths with respect to time (days) is shown in Fig. 1. It can clearly visulized from the figure that the tendrs of soil moisture are similar for all the depths.

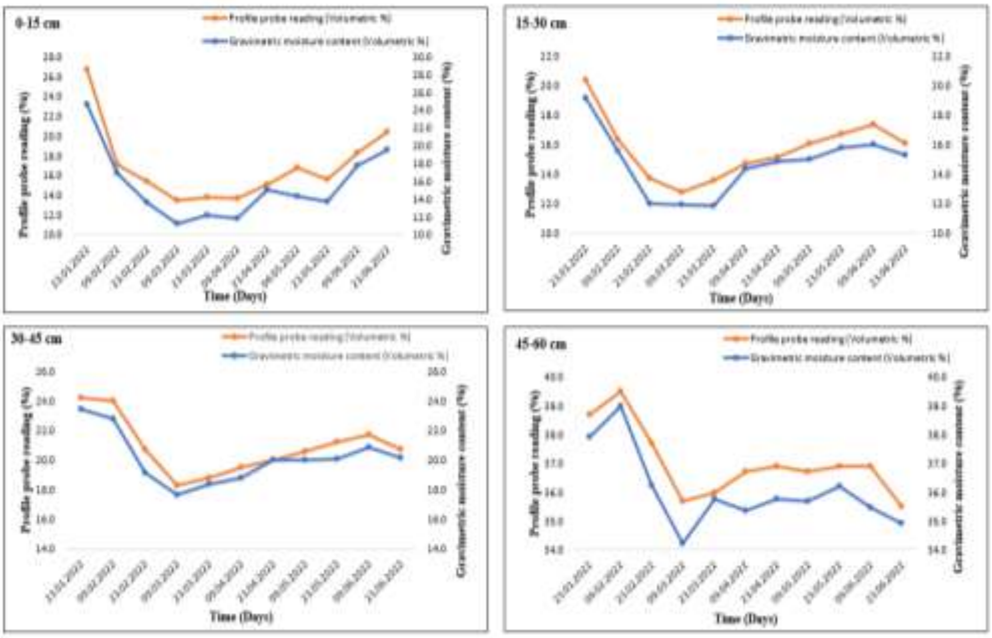

Fig.1: Compression of moisture content (%) measured using Profile probe and gravimetric method in 4 depths with respect to time (days)

Results of statistical analysis including coefficient of determination between the Permanent profile probe readings and the gravimetric moisture content data revealed a significant positive correlation since r^2 were found to be 0.9566, 0.9503, 0.9540 and 0.8945 for respective depths (Fig.2). Values of RMSE 1.622%, 1.108%, 0.857%) and 1.051% of the different depths *i.e* 0-15 cm, 15-30 cm, 30-45 cm and 45-60 cm, respectively also indicated close relationship between Permanent profile probe readings and the gravimetric moisture content data. It can be seen that a very good relation is established between both the two values. On the basis of these results it can be said that sensor data can be used for the purpose of irrigation management of horticultural crops.

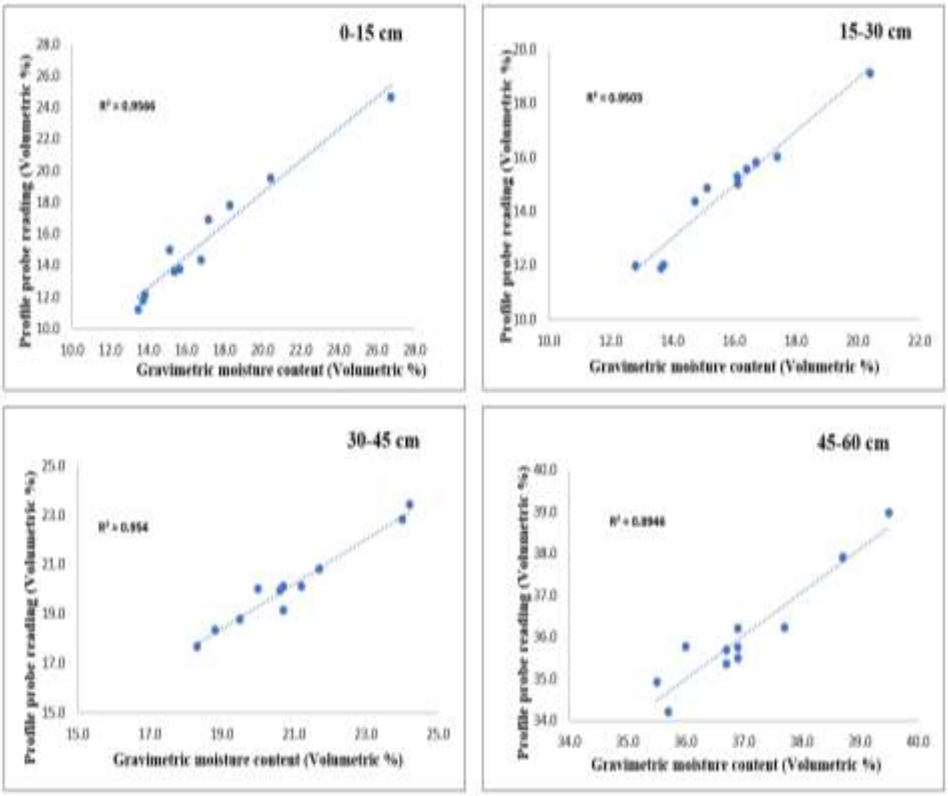

Fig.2: Scatter diagram between moisture reading taken from Profile probe and gravimetric method in 0-15 cm, 15-30 cm, 30-45 cm and 45-60 cm depths

Moisture Depletion and Leaf Area Index (LAI)

With the rapid expansion of modern agriculture, the timely and accurate monitoring of crop growth data are essential to agricultural precision management. In this study, the moisture depletion value was calculated by estimating the soil moisture content by the standard gravimetric method and the Leaf area index was recorded by a device called LAI 2200C Plant Canopy analyzer.

Moisture depletion and LAI of mango of Field-A

The moisture depletion values ranged between 7.20 to 15.81 % for 0-15 cm, 7.39 to 11.88 % for 15-30 cm, 10.59 to 14.02 % for 30-45 cm and 19.90 to 22.66 %for 45-60 cm, respectively and LAI of Mango tree of Field-A *i.e.* an open mango orchard including various varieties of mango trees in which randomly some trees were selected and data was recorded. There is little changes in trees canopy because of it's flowering stage as new leaf generation stage and then there was no significant changes in LAI of mango trees as the canopy of trees remained constant season wisebecause the age of trees was approximately 20 years old. The value of LAI of mangoorchard trees of Field-A varies from 3.29 to 4.46 during the study period. The depth-wise values of MD and LAI recorded from study area is given in Table 1.

Table 1: Moisture depletion (%) and LAI of mango of Field-A

Date	LAI	D 15 cm)	ID 5-30 cm)	MD (30-45 cm)	MD (45-60 cm)
3.01.2022	.29	81	.88	14.02	22.66
9.02.2022	.31	83	66	13.66	22.08

:3.02.2022	.34	2	47	11.47	21.06
)9.03.2022	.35	0	45	10.59	19.90
:3.03.2022	.38	0	39	10.99	20.80
)9.04.2022	.38	5	94	11.25	20.56
:3.04.2022	.4	0	23	11.99	20.79
)9.05.2022	.44	9	33	11.96	20.75
:3.05.2022	.45	2	83	12.04	21.05
)9.06.2022	.48	40	95	12.47	20.63
:3.06.2022	.46	52	50	12.05	20.30

Relationships between MD and LAI of brinjal of Field-A

Brinjal (solanum melongena L.) need a long period of at least five months togrow and can be perennial in frost-free areas. In this study, the variety Mukta Keshi was considered for analysis of it's growth and moisture depletion values collected twice a month. Brinjal was sown on November 20, 2021 but the analysis was started in the month of January. The data recorded is given in Table 2. The LAI value continuously increased till 140 DAS then suddenly started decreasing because of fruiting and shrinking and loss of leaves because of summer season. The soil MD values ranged between 7.20-15.81 %, 7.39-11.88 %, 10.59-14.02 % and 19.90-22.66 % and LAI values ranged up to 3.99 in the month of April.

Table 2: Data of moisture depletion (%) and LAI of Brinjal of Field-A

Date	DAS	LAI	MD (0-15 cm)	MD (15-30 cm)	MD (30-45 cm)	MD (45-60 cm
23.01.2022	64	1.78	15.81	11.88	14.02	22.66
09.02.2022	81	2.03	10.83	9.66	13.66	22.08
23.02.2022	95	2.63	8.72	7.47	11.47	21.06
09.03.2022	109	3.07	7.20	7.45	10.59	19.90
23.03.2022	123	3.43	7.80	7.39	10.99	20.80
09.04.2022	140	3.99	7.55	8.94	11.25	20.56
23.04.2022	154	3.78	9.60	9.23	11.99	20.79
09.05.2022	170	3.38	9.19	9.33	11.96	20.75

Relationships between MD and LAI of mango of Field-B

The depth considered was 0-15 cm and 15-30 cm, only these depths were analyzed because of rocky material after two depths. The soil MD values of mango orchard of Field-B *i.e.* dense mango orchard were found to be in between 7.26-15.13 % and 7.75-16.76 % of respective depths. The data of moisture depletion and LAI of brinjal of Field-A are given in Table 3.

Table 3: Data of moisture depletion (%) and LAI of mango of Field B

Date	LAI	MD (0-15 cm)	MD (15-30 cm)
23.01.2022	3.32	15.13	16.76
09.02.2022	3.37	9.18	11.42

23.02.2022	4.28	8.20	9.12
09.03.2022	4.31	8.02	9.32
23.03.2022	4.35	8.19	8.97
09.04.2022	4.34	8.07	8.84
23.04.2022	4.37	7.76	7.97
09.05.2022	4.37	7.54	7.75
23.05.2022	4.39	7.26	7.92
09.06.2022	4.4	7.64	8.29
23.06.2022	4.4	7.36	7.89

Conclusions

The validation results revealed that sensor based indirect method can be used successfully for soil moisture determination instead of gravimetric method as coefficient determination were turned out to be closer to 1 for all the depths and the RMSE were also tend to be satisfactory range from 0.8571 to 1.6223. The FDR probe moisture values and the soil sample measured values compared well. A very good relation is established between the values observed using FDR probe and gravimetric method. Hence this study shows that Permanent profile soil moisture probe moisture values can be used for soil moisture measurements. Results also revealed that the LAI of mango ranged between 3.29 to 4.46 and it tended up to 3.99 for brinjal. The LAI-2200C Plant Canopy Analyzer was found quite well and can be used for reading the LAI of mango and brinjal. .

References

1. Dente, L., Satalino, G., Mattia, F., and Rinaldi, M. (2008). Assimilation of leaf area index derived from ASAR and MERIS data into CERES-Wheat model to map wheat yield. *Remote Sensing of Environment*, 112 (4): 1395-1407.
2. Kirnak, H., Tas, I., Kaya, C. and Higgs, D. (2002). Effects of deficit irrigation on growth, yield and fruit quality of eggplant under semi-arid conditions. *Australian Journal of Agricultural Research*, *53*(12): 1367- 1373.
3. Michael, A. M. (2008). Irrigation Theory and Practice Second Edition, varied pages.
4. Roth, L., Aasen, H., Walter, A. and Liebisch, F. (2018). Extracting leaf area index using viewing geometry effects-A new perspective on high-resolution unmanned aerial system photography. *ISPRS Journal of Photogrammetry and Remote Sensing*, 141: 161-175.
5. Samant, A. P., Warang, O. S., Kulkarni, M. M., & Bhingarde, R. T.(2020) Relationship between plant canopy volume, leaf area index and yield in mango (Mangifera indica L.) cv. Alphonso., Pro. Of 8th Indian Horticulture Congress 2018 held at at Raipur, Chhattisgarh, DOI:10.13140/RG.2.2.19696.30723.
6. Shukla, A., Panchal, H., Mishra, M., Patel, P. R., Srivastava, H. S., Patel, P., & Shukla, A. K. (2014). Soil moisture estimation using gravimetric technique and FDR probe technique: a comparative analysis. *Am. Int. J. Res. Form. Appl. Nat. Sci*, (*8*)*:* 89-92.
7. Tavakoli, H., Mohtasebi, S. S., Alimardani, R., & Gebbers, R. (2017). Evaluation of different sensing approaches concerning to nondestructive estimation of leaf area index (LAI) for winter wheat. *Int. Journal on Smart Sensing and Intelligent Systems*, *7*(1):337-359.