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Correlation between the Soil Moisture Reading Obtained with Soil Moisture Sensors and Gravimetric Method for Scheduling of Irrigation in Maize

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Authors' contributions

This work was carried out in collaboration among all authors. Author DC designed the study, performed the research and statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors VR, MU and KS managed the analyses of the study and given guidance for the study. Author ES managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted at Water Technology Centre farm (WTC), College of Agriculture, Rajendranagar, Hyderabad for studying the correlation between the soil moisture reading obtained with soil moisture sensors and gravimetric method. The experiment was designed in split plot with two main treatments comprising of surface furrow (M1) and drip irrigation (M2) methods and six irrigation schedules were assigned to sub treatments and replicated thrice. Significantly higher grain yield (7.05 t ha^{-1}) of maize was observed with nano sensor (IITB) based irrigation scheduling over rest of the irrigation schedules except gypsum block. The results revealed that correlation between the tensiometer readings and gravimetric moisture content showed a negative non significant correlation before irrigation in surface furrow irrigation method and negative significant

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correlation for drip irrigation method. But in case of after irrigation a positive non significant correlation was observed in both drip and surface furrow irrigation methods. The gypsum block reading and gravimetric moisture content studies showed a negative significant correlation before irrigation in both surface furrow and drip irrigation methods, where as a positive non significant correlation between gypsum block readings and gravimetric moisture content readings were noticed after irrigation in both drip and surface furrow irrigation methods. Similar trend was recorded in nano sensor, except that it showed a positive significant correlation in both irrigation methods before irrigation. The correlation studies between the profile probe readings and gravimetric moisture content showed a negative significant correlation in surface furrow irrigation method at before and after irrigation, whereas, a positive significant correlation was observed after irrigation in drip irrigation method.

Keywords: Sensors; correlation; irrigation scheduling.

1. INTRODUCTION

Technology plays an important role in various sectors of farm management in today's commercial agriculture. Different techniques and tools have been developed to determine when and how much irrigation water needs to be used, especially in soil moisture sensor technologies that have proven successful in helping growers to manage irrigation [1]. The same production with less water supplies or higher production from the same water resources, helps to increase the productivity of crop water. Sensor-based irrigation planning creates an incentive for increasing the water productivity. This helps to conserve water by applying only when it is required. It not only conserves the water but also it improve the yield by overcoming the lacunas of gravimetric moisture measurement.

Mohamed et al. [1] based on Soil Moisture Sensors Systems (SMSS) in wheat conducted a study on automation of irrigation systems and that sensors viz., for soil drying tensiometers and watermarks were less responsive than gravimetric method. The resistance block sensors were depicting higher soil moisture tension but consistent in nature and it was observed to be best fit and the resistance block sensor remains a good tool for automatic irrigation scheduling [1]. Naglic [2] conducted a comparative study of Decagon 10 HS sensor and gravimetry in bitter gourd grown in silty clay loam soil. The results showed good agreement of volumetric water content measured with Decagon 10 HS & gravimetric method at two depths. It can be concluded that the sensor can be successfully used for irrigation scheduling. Kirnak and Akpinar [3] evaluated the TDR soil moisture sensors in a drip irrigated pumpkin *(Cucurbita pepo L.)* and indicated that measured soil water content values by TDR when compared with corresponding values derived from gravimetric samples showed that TDR-Slammer could be safely used as an acceptable, reliable and accurate method for measuring soil water content on loamy soil. Monicka et al. [4] scheduled irrigation by using granular matrix sensors (GMS) in a sprinkler irrigation schedule of maize (*Zea mays* L.) and observed a good correlation between sensor reading and gravimetric reading.

Reddy et al. [5] scheduled irrigation by gypsum block and reported a higher sugar beet yield (95 t ha^{-1}) along with saving of 18% water compared to the farmers practice. Chen et al. [6] and Simon et al. [7] reported a direct relationship between the maize grain yield and quantity of water applied through irrigation the maximum grain yield was obtained under fully irrigated treatment. Payero et al. [8] recorded maximum harvest index (61.77%) in fully irrigated treatment and low harvest index(28%) was observed when plants are subjected to water stress after tasseling Karam et al. [9] revealed that for partitioning of drymatter water plays an important role matter and application of optimum quantity of water results in better HI in maize crop. A field experiment was conducted based on this background at Water Technology Centre (WTC) Farm, Professor Jayashankar Telangana State Agricultural University, Rajendranagar (PJTSAU).Hyderabad (India) to study the correlation between soil moisture sensors and gravimetric soil moisture .

1.1 Objective of the Study

1. To compare the irrigation applications and water use under different sensor based irrigation scheduling practices for *rabi* maize grown under surface and drip method.

2. To monitor the soil moisture through gravimetric sampling and *in situ* evaluation of sensor technologies as tools for irrigation scheduling.
3. To correlate soil moisture sensor data with gravimetric soil moisture data and evaluate their field performance in irrigation scheduling

2. MATERIALS AND METHODS

The experiment was conducted at Water Technology Centre (WTC) Farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad. The farm is located at 17º19' 16.4" N latitude and 78º24' 43.7" E longitude and at an altitude of 542.6 m above mean sea level. With 12 treatments using DHM-117 as a test variety of maize, the experiment was laid out in a split plot design with three replications. Treatment combinations are listed in detail in Table 1.

2.1 Details of Treatments

There are two main treatment it is denoted as M1 and M2
M1 is surface furrow irrigation.
M2 is drip irrigation.

In addition to the two main treatments there are 6 subtreatments which is denoted as S1,S2,S3,S4,S5,S6 ie tensiometer,granulated gypsum block, profile probe, nano sensors(IITB),soil moisture indicator and IW/CPE ratio respectively.

For the treatment S-1 to S-6, irrigation were scheduled both in surface furrow irrigation and drip irrigation. When the tension reached 60-70 centibars(cbars) in tensiometer in (S1), 40-50 centi bars in gypsum block (S2) and 20-25 percent volumetric water content in profile probe (S3), 14-15 percent gravimetric humidity content in nano sensor (IIT-B) S4 red glow light indicator in (S5) and based on pan data in (S6) the irrigation was scheduled.

The basic principle involved in tensiometer is that the capillary tension increases with decrease in moisture content and in case of gypsum block the resistance reading decreases as increase in moisture content it works based on wheatson bridge principle. Neutron scattering method was used in profile probe.

Working method of nano sensor is given below

2.2 Collection of Data

1) WWW.Soil Sens.Com
2) Click on client login
3) Type username and password
4) Click on login
5) Download soil moisture data and graph.

The mode of operation, is that the sensor rods of SMI need to be inserted into the soil to a required depth to assess the soil moisture, which is indicated by glowing LEDs

The data obtained from the field experiment was statistically analyzed by applying variance analysis techniques (Gomez and Gomez, 1984). The table values were compared to the F treatment values. If the results were significant, critical differences were estimated at the 5 percent significance level. Web Agri Stat Package data analytical package (Web Agri Stat Package) ver 2.0 was used for data analysis. For the data on characterisation studies, the means and standard deviations were calculated. Any relationship between two random variables or bivariate data is known as association or dependence. Correlation is statistical relationships involving dependence, it most often refers to how close two variables are to having a linear relationship with each other and the value varies from -1 to +1. Correlation between the soil moisture reading obtained with soil moisture sensors and gravimetric method is studied.

Tables 1. Indicator readings of soil moisture status of SMI

Colour of LED	Soil Moisture Status	Inference
Blue	Ample moisture	No need of irrigation
Green	Sufficient moisture	Immediate irrigation may not be necessary
Orange	Low moisture	Irrigation advisable
Red	Very low moisture	Immediate irrigation necessary

In case of IW/CPE ratio the irrigation water was applied on the basis of pan evaporation (PE) data (USWB open pan evaporimeter) obtained from the Agromet Center, ACRC, Rajendranagar, Hyderabad

3. RESULTS AND DISCUSSION

3.1 Tensiometer Readings and Corresponding Gravimetric Moisture Content Readings Before and After Irrigation

Tensiometer readings observed and corresponding gravimetric moisture content determined before and after each irrigation as per irrigation scheduling. Perusal of data indicates that tensiometer readings at which the irrigation was triggered ranges from 62.67-66.33 cbars before irrigation and 0.67-1.33 cbars was the range observed after irrigation in surface furrow irrigation. The corresponding gravimetric moisture content (%) range (14.05-15.19%) before irrigation was less observed in each irrigation cycle, it increased after irrigation to a range of 20.91-23.58%. in surface furrow method. Similar trend was observed in drip irrigated plot wherein the tension readings observed before irrigation at which irrigation was triggered ranges between 63-67.33 cbars and corresponding gravimetric moisture content ranges from 13.54-15.03%.Whereas the tension readings noticed after irrigation ranges between 0.67-1.33 cbars with a corresponding gravimetric moisture content of 20.41-21.91%. The correlation studies between the tensiometer readings and gravimetric moisture content showed a negative non significant (-0.37) correlation before irrigation in surface furrow irrigation method and negative significant correlation (-0.47*) for drip irrigation method (Table 2. and 3). Mohamed et al. [1] concluded that tensiometers were very less responsive to soil moisture drying than gravimetric method. A positive non significant correlation between tensiometer reading and gravimetric moisture content was observed after irrigation in both drip (0.29) and surface furrow (0.08) irrigation methods.(Table 4. and 5).This finding was in true with results obtained from the experiment conducted in Delhi to evaluate the effectiveness of tensiometer and gravimetric method, where in a good correlation was obtained between sensor reading and gravimetric moisture content after irrigation [10].

3.2 Gypsum Block Readings and Corresponding Gravimetric Moisture Content Readings Before and After Each Irrigation

The data pertaining to gypsum block readings and corresponding gravimetric moisture content determined before and after each irrigation as per irrigation scheduling are presented in Table 2. and Table 3. Gypsum block readings observed ranges from 41.33-47.33 cbars before irrigation and zero to two cbars after irrigation. The corresponding gravimetric moisture content (%) estimated before irrigation was in the range of 14.58-17.89% and it increased to a range of 20.57-22.50% after irrigation in surface furrow method. Whereas, drip irrigated plots the gypsum block readings ranges between 42.33-46.67 cbars before irrigation with corresponding gravimetric moisture content ranges of 14.94-17.32%. The gypsum block reading noticed after irrigation ranges between 0.67-2.0 cbars with corresponding gravimetric moisture content of 20.65- 21.27%. The correlation studies between the gypsum block reading and gravimetric moisture content studied showed a negative significant correlation before irrigation in both surface furrow (-0.69**) and drip irrigation (-0.47*) method.(Table 1. and 2). It suggesting that gypsum blocks gives more response in drier condition. However, positive non significant correlation between gypsum block reading and gravimetric moisture content was noticed after irrigation in both drip (0.06) and surface furrow (0.27) irrigation methods Table 4. and 5. Monicka et al. [4] recorded a good correlation between gypsum block reading and gravimetric moisture content (%).

3.3 Profile Probe Readings and Corresponding Gravimetric Moisture Content Readings Before and After Irrigation

Profile probe reading (volumetric moisture) observed before irrigation ranges from 19.92-23.60% and it increased to 29.86-32.01% after irrigation. The corresponding gravimetric moisture content (%) noticed was less before irrigation (in the range of 15.96- 16.98%) and it increased after irrigation to 21.15- 22.03% range in surface furrow irrigation method. Whereas in drip irrigated plots probe readings ranges between 21.07-23.13%, with corresponding gravimetric moisture range of 16.26- 17.07% before irrigation and a probe readings in the range of 28.55-33.75% and corresponding gravimetric moisture content reading 20.62-21.42% after irrigation. Profile probe gravimetric reading (%) and corresponding gravimetric moisture content (%) recorded high deviation before irrigation in both surface (+/- 4.64-23.51) and drip (+/- 8.10-20.27) irrigation methods .Whereas profile probe readings (%) and

Table 2. Correlation between sensor reading and gravimetric moisture content (%) before irrigation in surface furrow method

	Tensiometer Reading (cbars)	Gravimetric moisture content (%)	Gypsum block reading (cbars)	Gravimetric moisture content (%)	Profile probe reading (%)	Gravimetric moisture content (%)	Nano sensor (%)	Gravimetric moisture content (%)
	64.67	14.16	44.00	15.88	21.12	16.98	14.25	16.79
	63.67	14.40	43.33	17.01	22.75	16.40	15.13	16.77
	65.67	14.48	41.67	15.80	21.35	15.96	14.50	14.87
	64.67	15.19	43.00	16.32	19.92	16.80	14.65	15.64
	62.67	14.76	43.67	17.07	21.92	16.54	14.27	15.60
	66.00	14.70	47.33	14.58	23.55	16.26	12.73	14.59
	66.33	14.05	45.67	16.10	20.90	16.23	13.23	16.41
			46.33	16.13	21.83	16.57	13.90	15.58
			44.00	16.65	23.60	15.96	14.40	16.55
			42.67	17.83	22.25	16.78	13.37	16.01
			41.33	17.89	22.58	16.22	14.00	15.65
			41.33	17.00			14.50	16.70
r_{cal}	r= -0.37		r= -0.69**		r= -0.42*		r=0.42**	
No. of irrigations	7		12		11		12	
No. of replications	3		3		3		3	
dof (n-2)	19		34		31		34	
r at 5% LOS	0.43		0.33		0.34		0.33	
r at 1% LOS	0.41		0.42		0.45		0.42	

Table 3. Correlation between sensor reading and gravimetric moisture content (%) before irrigation in Drip method

	Tensiometer reading (cbars)	Gravimetric moisture content (%)	Gypsum block (cbars)	Gravimetric moisture content (%)	Profile probe (%)	Gravimetric moisture content (%)	Nano sensor (%)	Gravimetric moisture content (%)
	65.00	14.83	46.67	15.98	21.07	16.92	14.90	16.25
	64.00	13.54	43.67	16.94	22.39	16.93	18.17	17.07
	63.67	14.40	46.33	16.94	22.78	16.52	16.23	16.58
	65.00	14.38	46.33	16.73	22.80	17.02	17.87	16.31

	Tensiometer reading (cbars)	Gravimetric moisture content (%)	Gypsum block (cbars)	Gravimetric moisture content (%)	Profile probe (%)	Gravimetric moisture content (%)	Nano sensor (%)	Gravimetric moisture content (%)
	63.00	14.23	45.67	16.43	21.11	17.07	16.77	17.02
	68.00	13.59	43.33	17.07	22.75	16.57	14.90	16.97
	65.00	14.30	46.00	14.94	21.79	16.26	13.63	14.88
	66.33	15.03	42.33	16.77	22.54	16.75	17.73	16.68
	67.33	14.21	44.33	17.21	23.08	16.39	16.33	17.19
			44.33	17.26	23.13	16.49	17.00	16.50
			45.33	17.32	20.55	16.09	16.77	16.60
			44.00	17.08	24.27	17.03	16.00	16.08
			43.67	17.10	21.98	16.94	16.17	16.58
			46.00	15.00			16.03	17.94
r_{cal}	r= -0.47*		r= -0.60**		0.30*		r= 0.43**	
No. of irrigations	9		14		13		14	
No. of replications	3		3		3		3	
dof (n-2)	25		40		37		40	
r at 5% LOS	0.38		0.30		0.31		0.30	
r at 1% LOS	0.48		0.39		0.40		0.39	

Table 4. Correlation between sensor reading and gravimetric moisture content (%) after irrigation in surface furrow method

	Tensiometer reading (cbars)	Gravimetric moisture content (%)	Gypsum block (cbars)	Gravimetric moisture content (%)	Profile probe (%)	Gravimetric moisture content (%)	Nano sensor (%)	Gravimetric moisture content (%)
	0.67	21.96	0.67	21.57	30.39	21.76	16.60	21.24
	1.33	20.91	2.00	21.43	30.59	21.41	16.55	20.19
	0.67	21.59	1.33	22.50	29.86	21.46	16.01	24.11
	1.33	21.84	0.67	22.46	31.18	21.29	19.00	23.61
	0.67	21.75	0.00	20.57	30.71	21.15	14.78	19.42
	1.33	23.58	1.33	22.22	28.88	21.45	16.62	22.76
	1.33	20.94	1.33	21.47	29.10	22.03	19.05	21.54
			2.00	20.94	30.34	21.31	18.26	20.75
			0.67	21.15	32.01	21.70	20.69	21.02
			0.00	20.98	31.12	21.96	20.55	21.08
			0.67	20.68	31.05	21.58	16.28	21.08

	Tensiometer reading (cbars)	Gravimetric moisture content (%)	Gypsum block (cbars)	Gravimetric moisture content (%)	Profile probe (%)	Gravimetric moisture content (%)	Nano sensor (%)	Gravimetric moisture content (%)
			1.33	20.96			18.49	21.02
r_{cal}	r= 0.08		r= 0.27		r= -0.72**		r= 0.06	
No. of irrigations	7		12		11		12	
No. of replications	3		3		3		3	
dof	19		34		31		34	
r at 5% LOS	0.43		0.33		0.34		0.33	
r at 1% LOS	0.41		0.42		0.45		0.42	

Table 5.Correlation between sensor reading and gravimetric moisture content (%) after irrigation in drip method

	Tensiometer reading (cbars)	Gravimetric moisture content (%)	Gypsum block (cbars)	Gravimetric moisture content (%)	Profile probe (%)	Gravimetric moisture content (%)	Nano sensor (%)	Gravimetric moisture content (%)
	1.33	20.68	1.33	20.65	33.04	21.25	18.60	20.43
	0.67	20.41	1.33	20.95	31.27	20.75	21.23	22.49
	1.33	21.56	1.33	20.76	31.74	21.06	21.17	21.35
	1.33	21.81	1.33	21.24	33.75	21.33	20.80	22.64
	0.67	21.91	1.33	20.95	30.77	20.76	19.27	22.60
	0.67	20.59	0.67	20.96	31.40	21.26	17.40	21.51
	1.33	21.16	1.33	21.27	33.65	20.62	22.67	20.51
	0.67	21.19	2.00	20.63	30.95	21.42	20.67	21.49
	1.33	20.78	1.33	20.37	30.67	21.03	21.57	21.05
			1.33	20.70	31.94	20.99	21.57	21.05
			1.33	20.90	28.55	20.67	19.17	20.79
			0.33	20.53	31.60	20.75	20.80	21.15
			1.67	20.82	30.39	21.53	16.03	20.91
			1.33	20.71			19.03	20.97
r_{cal}	r= 0.29		r= 0.06		r= 0.06		r =0.02	
No. of irrigations	9		14		13		14	
No. of replications	3		3		3		3	
dof	25		40		37		40	
r at 5% LOS	0.38		0.30		0.31		0.30	
r at 1% LOS	0.48		0.39		0.40		0.39	

gravimetric moisture content (%) showed less deviation after irrigation in both surface (+/- 4.84-14.80) and drip (+/- 0.33- 10.89) irrigation methods. The correlation studies between the profile probe readings and gravimetric moisture content showed a negative significant correlation in surface furrow irrigation method before (-0.42*) and after (-0.72**) irrigation(Table 2. and 4).Whereas, a positive significant correlation between the profile probe reading and gravimetric moisture content was observed before irrigation (0.30*) and positive non significant correlation was observed after irrigation (0.06) in drip irrigation method(Table 3. and 5). This findings was supported by Yan et al. [3] conducted an experiment in order to obtain accurate real-time soil moisture data and the spatial distribution of soil moisture measurement based on neutron probe in comparison to gravimetric method showed that the sensor is suitable for measuring the moisture content of different type of soil at a measurement accuracy of ± 1.31% with better stability and consistency with good correlation between probe reading and gravimetric moisture content (%).

3.4 Nano Sensor (Iit-B) Readings and Corresponding Gravimetric Moisture Content Readings Before and After Irrigation

Nano sensor reading ranges from 12.73-15% before irrigation and 15- 20.69% after irrigation and the corresponding gravimetric moisture content (%) recorded before irrigation was less in the range of 14.59-16.79% and it increased after irrigation to a level of 19.42- 24.11% range in surface furrow irrigation method. Similar trend was observed in drip irrigated plot where in the nano sensor triggered moisture range observed between 13.63- 18.17% before irrigation with corresponding gravimetric moisture content ranges from 14.88-17.94%. Whereas, the nano sensor reading noticed after irrigation ranges from 16.03-22.67% with corresponding gravimetric moisture content of 20.43- 22.64%. Nano sensor readings (%) move very closely with gravimetric moisture conent (%) with a percent deviation of +/- 2.49-15.13 in surface furrow irrigation and +/- 0.50- 12.20 in drip irrigation method .at before irrigation. Whereas in case of after irrigation the readings recorded more deviation at surface (+/- 1.57- 26.98) and drip (+/- 0.84- 23.34) irrigation method. The correlation studies between the nano sensor reading and gravimetric moisture content showed a positive significant correlation before irrigation (0.42**, 0.43**) and positive non significant correlation after irrigation (0.06, 0.02) in both surface furrow and drip irrigation method respectively. (Table 4 and 5).This finding was similar to the results indicated by Kirnak and Akpinar [3] in pumpkin where in that measured soil water content by TDR soil moisture sensor and the corresponding values derived from gravimetric samples showed good correlation between each other.

4. CONCLUSION

Insitu evaluation of sensor technologies with gravimetric moisture content revealed that before irrigation the nano sensor readings moved very closely with gravimetric moisture content readings in both surface and drip irrigation methods. Deviation between observed nano sensor reading and gravimetric moisture content was less, suggesting that it works better in drier condition. Whereas, profile probe readings and gravimetric moisture readings showed less deviation after irrigation in both surface and drip irrigation method. The nano sensor (IITB) based irrigation scheduling followed in *rabi* maize showed a positive correlation between gravimetric moisture content and the sensor readings in both surface and drip irrigation methods at before and after irrigation. So it is assumed to be best among the irrigation scheduling methods

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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