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Review Paper

Different types of soil moisture sensors in agriculture: a review

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ABSTRACT

Non optimal use of water has paved a way for management of water and its resources on the globe. One of the way to increase the proficiency of water usage to the crop, is to prognosticate the proper estimates of water requirement to the crop both in time and space. The logistics of acquisition of the real time data of soil moisture status of the crop using soil moisture sensors is a way effective blueprint for managing the sustainability of Agricultural water to future originations. This ramification not only, will demote the strain on the farmer contemporaneously but simultaneously parlay the sustainability of the soil and thus, ecosystem in exclusive. This review was undertaken to investigate the surfeit and novelity of soil moisture sensors, and examine their prospective use in Agriculture. The review found that improvements to existing techniques over the last two decades are limited, and largely restricted to frequency domain reflectometry approaches. Tensiometers are simple to use and inexpensive unlike TDR and FDR however, usage is restricted to sandy soils only. GMS is less expensive but sensor and soil might sometimes make poor contact. TDR are FDR are extremely accurate. VH400 Soil Moisture Sensor responds quickly, takes readings in seconds.

Keywords: Dielectric constant, FDR, soil moisture probes, TDR, tensiometer

Comprehension of soil moisture is foremost for supporting agricultural production, flood forecasting, catchment hydrology, landslide prediction and other ecosystem services (Tuller *et al*., 2019). 70% of the fresh water is utilised for agriculture each year, or 1,500 billion m^3 out of 2,500 billion m^3, is used for agriculture (Shah and Das, 2012). Non-optimal water use is one of the main issues in agriculture. According to estimates, 40% of the fresh water used for farming in underdeveloped nations is wasted due to spillage, evaporation, absorption by the deeper layers of the soil, where plant roots cannot reach (Shah and Das, 2012). Today, it is commonly acknowledged that managing agricultural water is a significant challenge that is frequently correlated with problems related to development. Numerous freshwater resources have been harmed by agricultural activity due to overuse, fertilizer pollution, and salinization (Thompson *et al*., 2007). Water requirements for irrigation have been the subject of numerous studies (Shen *et al*., 2013). The artificial application of water to agricultural land is known as irrigation, and it is regarded as one of the most crucial elements of agriculture. Due to the lack of water in some areas, it is important to use water properly, which means only providing it where it is required and in the necessary quantity. Drip irrigation, sprinkler irrigation, and other irrigation techniques are used to address the issue of water waste in conventional techniques like furrow irrigation and flood irrigation (Aqeel *et al.*, 2014). The gap between the crop water requirement and the amount of precipitation that would be effective is essentially represented by the irrigation water requirement (Allen *et al*., 1998). By integrating the modified Penman-Monteith equation proposed by the FAO and GIS technology (Shen *et al*., 2013), irrigation water demand as well as crop water requirements can be predicted. Irrigation water demand, according to Shen *et al*. (2013), is crucial to the distribution of water resources for the benefit of the economy and natural ecosystems in the highly water-scarce region. Improved irrigation scheduling depends on knowing the water requirements of crops (Shankar *et al*., 2012). Therefore, a method for figuring out when water needs to be applied to the fields is needed. The farmer's workload would be reduced by this system, and it would also help them to maintain healthy soil for increased crop output. The ability to build systems that do not directly engage the farmer in the irrigation of their crops is thus made possible by advances in technology (Chanda *et al*., 2012). In order to accurately track the status of soil water in agricultural fields, a novel method of gathering real-time data from the field using soil moisture sensors holds considerable promise. An immense gamut of soil moisture sensors have been promoted in Agriculture sector viz tensiometers, Granular matrix sensor (GMS), Frequency Domain Reflectrometry (FDR), Time Domain Reflectrometry (TDR), VH400 Soil Moisture Sensor. Soil moisture sensors hold up promising potential in irrigation scheduling and in preventing irrigation losses (Yin *et al*., 2021). Above all, sensor based irrigation to crops is one of the innovational methodology for agricultural sustainability (Kayad *et al*., 2020). Nevertheless, adoption of these sensors for monitoring soil moisture is inadequate. Poor adoption is anticipated for operational constraints and soil constraints. Operational costs like data volume, poor soil sensor contact, cost, difficulty in installation etc (Babaeian *et al*., 2019). Soil constraints like sensor failure in the event of saline soils, stony soils etc. Poor adoption is mainly due to the limited knowledge on these sensors. Thus, this review paper's major goal is to discuss the necessity of sensors-based technology for an automatic irrigation system that may be utilized to maximize water use while saving the farmer money, electricity, and time.

Different types of Sensors: Today we find different types of sensors which work uniquely (Francesca *et al*., 2010). They measure soil water potential, soil water content and dielectric constant (volumetric content). The soil water tension based sensors (granular matrix sensors and tensiometers) and soil water content based sensors (FDR, TDR, and VH400 are reviewed here, despite the fact that there are many ways available for measuring soil moisture.

Fig. 1: Tensiometer

Tensiometers: Tensiometers are basic instruments for gauging soil moisture tension, and they are often employed in irrigation planning. Figure 1 depicts a conventional tensiometer, which has a porous ceramic tip connected to a vacuum gauge by a PVC tube. Water that fills the tube should be devoid of air. The porous ceramic cup is inserted into the ground in such a way that soil water pressure is communicated to the tensiometer and measured by pressure sensing equipment positioned on the tensiometer This tool monitors soil water tension rather than soil moisture content (Freeman *et al.,* 2004). A tensiometer typically responds within two to three hours (Zazueta and Xin, 1994).

Advantages:

a) Tensiometers are direct, quick, affordable, and simple to use (Enciso-Medina *et al.,* 2007).
b) Data can be obtained under freezing and thawing conditions using various liquids, such as ethylene glycol solution (Schmugge *et al.,* 1979).
b) For sandy loam or light-textured soils, a tensiometer is ideal (Alam and Rojers, 1997).

Disadvantages:

a) As air bubbles build up with regular use, periodic maintenance is necessary (Hensley *et al*., 1999).
b) Freezing conditions make it susceptible to harm (Alam and Rojers, 1997).
c) Since they only measure soil water potential in the area around the tensiometer, several tensiometers are needed for the measurement (Goodwin, 2009).
d) The gauge's usable range is confined between 0 and 85 centibars of tension; any higher than that will cause it to malfunction (Werner, 2002).

Granular Matrix Sensor (GMS): As depicted in figure 2, the granular matrix sensor is composed of an external porous ceramic shell and an inside matrix structure with two electrodes. The granular fill layer over the gypsum wafer contains embedded electrodes that are part of the GMS. The variation in the corresponding water conditions in the soil affects the water conditions in the granular matrix, and the sensor continuously detects these variations by the difference in electrical resistance between the two electrodes (Berrada *et al*., 2001). The relationship between the electrode resistance and soil water is inverse (Irmak *et al*., 2006).

Fig. 2: Granular matrix sensor (GMS)

Advantages:

a) When compared to tensiometers, GMS is less expensive and requires less maintenance (Shock *et al*., 1998).
b) It is possible to automate watering in fields (Munoz-Carpena *et al*., 2005).
c) Minimal variation in sensor performance with soil temperature changes (Irmak and Haman, 2001).

Disadvantages:

a) It has varying responses to various soil types (Enciso-Medina *et al.,* 2007).
b) The sensor and soil might sometimes make poor contact, which could result in high readings. This is most likely to happen in heavy soils (Berrada *et al.,* 2001).
b) It responds less quickly to light rain.

Time Domain Reflectometry (TDR): In time domain reflectrometry, the velocity of a radio frequency energy pulse is determined by detecting the pulse that is reflected from the end of the transmission line (Fig. 3) The dielectric constant affects this velocity. The amount of moisture is determined by timing how long it takes for the reflected pulse to return (Cepuder *et al*., 2008). A TDR responds in less than 28 seconds (Zazueta and Xin, 1994).

Fig. 3: Time domain reflectometry (TDR)

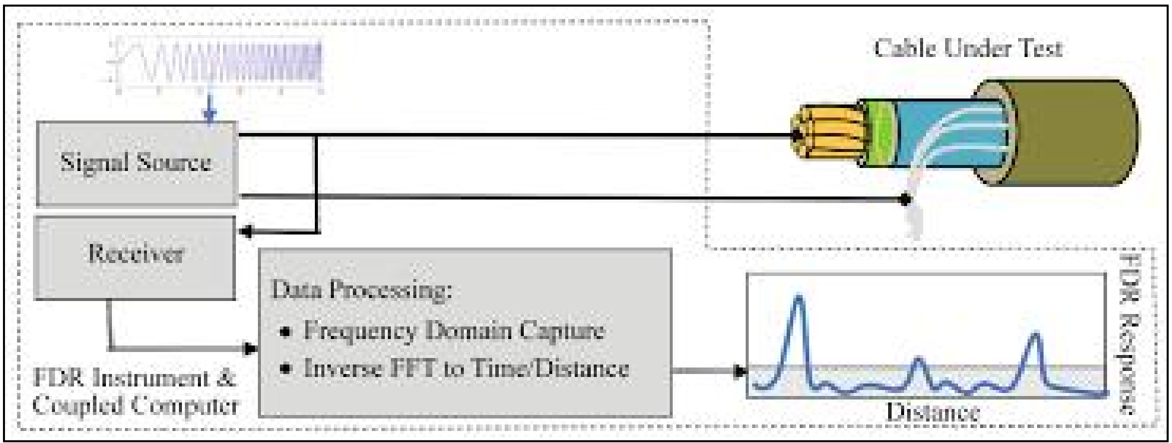
Advantages:

a) TDR react promptly to changes in soil moisture (Marenghi, 2013).
b) It monitors moisture in any type of soil with high accuracy (2%) (Cepuder *et al*., 2008).
c) A single probe can measure the moisture content of soil at various depths (Pitts, 2016).
d) The test site experiences little to no disruption while being tested (Skierucha *et al.,* 2012)

Disadvantages:

a) They must be precisely calibrated in order to measure the time it takes for the pulse to return (Paige *et al*., 2008).
b) This tool is more expensive than other measuring techniques (Zazueta and Xin, 1994 and Heiniger, 2013).
c) Limited TDR applications because of high costs (Blonquist *et al*., 2005).
d) TDR only measures soil moisture close to the sensor (Wolpert *et al*., 2013).

Frequency Domain Reflectometry (FDR): The soil sample serves as the dielectric in the FDR sensor, which is made up of two metal rings that are fashioned into capacitors (Figure 4). Soil volumetric content can be measured directly using the electrical sensor capacitance. It works on a similar concept as a TDR sensor.



Advantages:

a) If calibrated correctly, it is extremely accurate (1%) (Munoz-Carpena *et al*., 2004).
b) In contrast to TDR, it can be employed with highly salinized soil (Munoz-Carpena *et al.,* 2004).
c) FDR allows measurements to be taken simultaneously at various depths (Abouatallaha *et al.*, 2011).
d) In comparison to TDR, it is more expensive (Maughan *et al*., 2015).

Disadvantages:

a) Soil-specific calibration is necessary (Linmao *et al*., 2012).
b) In order to prevent air gaps from forming during FDR, it is important to have adequate contact between the soil and the sensor (Munoz-Carpena *et al*., 2004).
b) It can only detect moisture content close to the sensor (Wolpert, 2013)

VH400 Soil Moisture Sensor: The resistive-based VH400 soil moisture sensor monitors the soil's dielectric constant (Salih *et al.,* 2013). It aids in accurate, inexpensive soil water content monitoring. It responds quickly, takes readings in under a second, and is significantly more sensitive at greater volumetric water contents (Ravi *et al*., 2011). A horizontal location at the root level is preferred for inserting the soil moisture probe into the ground. This sensor is compact, strong, water-resistant, and uses less electricity. Additionally, it is resistant to corrosion over time, insensitive to water salinity (Zaier *et al.,* 2015), and sensitive to even minute changes in water content (Bitella *et al*., 2014). Temperature measurement is always necessary because this sort of sensor is sensitive to temperature variations in wet situations (Bitella *et al*., 2014). In order to create a wireless sensor network, the probe is typically connected to a soil moisture reading device; such networks are widely employed in precision agriculture and smart irrigation (Khriji *et al*., 2014). One of these tools is a soil moisture data recorder, which shows digital readings of moisture content. The system (figure 5) has two ways to communicate with remote users: first, readings are provided via Short Messaging Service (SMS) on the GSM network, and second, readings can be stored on a memory card and then downloaded to a computer for analysis.

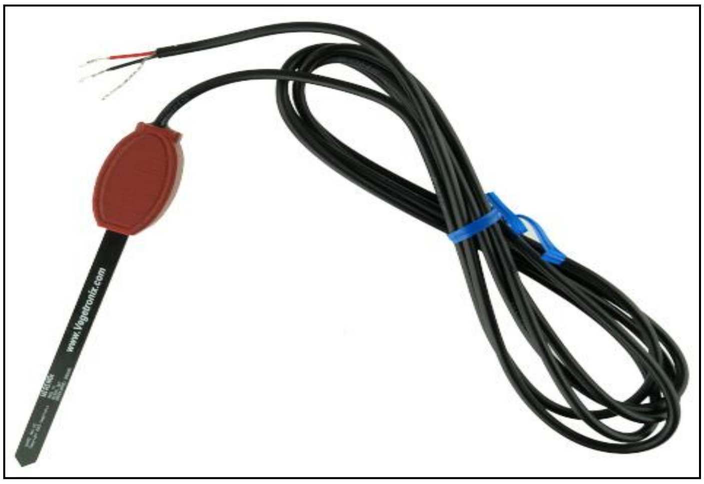


Fig. 5: VH400 Soil Moisture Sensor

CONCLUSION

Many farmers in semi-arid regions of developing countries who cannot afford to pay for powered irrigation significantly rely on the rains for their crops. It has been noted that farmers suffer significant financial losses as a result of inaccurate weather forecasts and inadequate irrigation techniques. The goal is to develop an intelligent irrigation scheduling system that will enable irrigation farmers to optimise the use of water and only irrigate where and when necessary for as long as needed. There is a genuine need to improve the efficiency of irrigation systems and prevent the non-optimal use of water. Soil moisture sensors detect any changes in the surrounding environment's temperature and humidity and send an interrupt signal to the irrigation system. The development of solutions for the majority of agricultural operations linked to irrigation and other agricultural processes is aided by the sensor technology that has been discovered to be suitable for gathering real-time data for various aspects relevant to weather, crops, and soil. The development of wireless sensor applications in agriculture has made it feasible to boost farming operations' productivity, efficiency, and profitability.

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