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SOIL MOISTURE SENSOR RESEARCH PAPER

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Abstract: The determination of the moisture content of the soil serves as the foundation for the improvement of agricultural practises that lead to the implementation of irrigation systems that use less water. On the basis of its theoretical foundation and an investigation into the dielectric constant properties of soil, a brand-new moisture sensor for soil has been developed. It is primarily made up of various probes, electronic circuits, and cables for wiring. The sensor was put through its calibration process at a working voltage of between 2.5 and 5.5 volts during the test. After conducting an analysis of the regression function based on the experimental data, it was discovered that the output voltage of the sensor ought to have a linearly negative correlation with the volumetric moisture content of the soil, and that the coefficient of determination R2 ought to be greater than 0.98. The precision of the sensor was tested using soil samples that varied in their level of moisture content. The standard deviation of the absolute value of errors is lower than 2.5 percent on average. According to the findings, the sensor possesses a working performance that is consistent and reliable, high measurement accuracy, and good linearity, and it is suitable for moisture measurement in the vast majority of different types of soil.

Keywords: Theoretical foundation, calibration process, irrigation systems, moisture measurement.

1. Introduction

The presence of water is an essential component of the soil, and it is one of the primary elements that determines the development and production of crops. The determination of the moisture content of the soil serves as the foundation for the improvement of agricultural practises that lead to the implementation of irrigation systems that use less water. The accurate observation and calculation of soil moisture, as well as the development of a model to accurately predict soil moisture content, have significant and important practical implications for agricultural production.

At the moment, the method for determining the moisture content of the soil can be split up into two distinct categories. One of these is the measurement of changing locations throughout the sampling process. For example, a method of drying and weighing the product. The other method is known as measurement in a fixed position. Methods like neutron, gamma ray, time domain reflector, frequency domain emitter, and sensor are examples of such methods. The method of drying and weighing is straightforward and has a high degree of precision, but it was not possible to carry out continuous monitoring in the field in real time. Both the neutron method and the gamma ray method were capable of monitoring the soil moisture content quickly and accurately; however, there were issues with radioactive substances that were hazardous to human health. The dielectric constant method, which is based on the capacitance principle, was used more frequently because it was easier to implement technically, was less expensive, was more accurate, and could be done in real time. By utilising an indirect method of measuring the soil's dielectric property, this method is able to accomplish the rapid and non-destructive measurement of the soil's moisture content. The majority of the sensing components of the sensors that were used were plug-in structures that had straightforward geometrical structures and were straightforward to fabricate. In spite of this, the majority of the measurement signals required conditioning, the circuit was relatively complicated, and it was constrained by the size and strength of the sensing components; as a result, measuring the moisture content of deep soil was a challenge.

The primary focus of this article was on a recently developed model of damage-free and high-performing soil moisture sensor. The consistency and dependability of its work performance, along with its high measurement accuracy and good linearity, are all advantages. According to the findings of the research, the sensor is capable of satisfying the requirements of practical application and is appropriate for measuring the majority of different types of soil moisture.

Soil properties: The combination of the various types of retrieval systems with the mineral particles that are present in the soil is used to determine the classification of the soil's texture. The international classification system classifies the texture of the soil into thirteen different levels and four distinct groups: sand, loam, clay-loam, and clay.

The term "soil electrical properties" refers to the soil's physical and electrical properties, which are distinct from its electrochemical properties. These properties include the natural electric field (electric potential), resistance (conductivity), electroosmosis, and dielectric constant of the soil. Other examples of soil electrical properties include electroosmosis and dielectric constant. In addition, the relationship between soil conductivity and soil resistance is inverse. In most cases, it is utilised to ascertain the moisture content or salinity of the soil, as well as the boundary of distribution for particular soils. These characteristics of the soil serve as a conceptual foundation for the process of measuring soil moisture.

2. Literature survey

To begin, a comprehensive mathematical analysis on four different analytical methods is presented. These include the "Kirchhoff Approximation Model ()" (Pinel et al., 2020); the "Integral Equation Model ()" (Zhang et al., 2020); the "Small Perturbation Model ()" (Burkholder et al., 2017); and the "Small Slope Approximation Method ()" (Z whereas and are considered to be the more modern approach for monitoring scattering from rough surfaces with a large validity range, and are thoroughly explained in the manuscript through mathematical derivations of these models. and are considered to be the earliest approach to analyse scattering caused due to the rough surfaces, whereas and are considered to be the more modern approach for monitoring scattering from rough surfaces. In conclusion, a concise overview of these methods along with their limitations is presented. In addition, the model responses and constraints that correspond to the "less rough surface" and the "rougher surface" are presented in the section of the manuscript that is titled "discussion."

A numerical simulator for calculating the power ratio and the electromagnetic scattering in the "specular direction" was developed by Gu et al. (Gu et al., 2019). In the course of this research project, it is assumed that the investigation will take place in a region where the position of the specular point will be in the site's centre. During the process of integrating the surface discretization, a dimension for the total number of patches is taken. During the course of this investigation, it came to light that the outcomes of the power ratio and the Kirchhoff simulator differ depending on whether or not the models were coherent or incoherent. Last but not least, the author has arrived at the conclusion that the power ratio of the Kirchhoff simulator is high for the incoherent model and low for the coherent model. Based on and electromagnetic theory of stratified media, Tian et al. (Tian et al., 2017) developed a new method to calculate "bistatic scattering coefficients." The newly developed method is able to complete the task - times quicker than the "Method of the Moment." The recently developed method cuts down on the need for large matrix inversions, as well as computation time, memory requirements, and overall computational efficacy.

An exhaustive study on "synthetically surface profiles" has been presented by Lievens et al. (Lieevens et al., 2009) in order to identify the error that is generated on the roughness parameter when standard scattering techniques are used. They continued by describing the process that should be used to correct these errors. As a result of their investigation, they came to the conclusion that certain factors that contribute to the error in the roughness parameter include "surface profile length," "number of profile measurements," "vertical and horizontal accuracy of the profile," and "removal of trends along with profile." In addition to this, they came to the conclusion that the retrieval of soil moisture (SM) along band had a lower total number of inaccuracies when compared to the band configuration. Zribi et al. (Zribi et al., 2000) provided a detailed account of the SIRC/XSAR mission that took place in 1994 at the Orgeval location. It is possible to obtain satellite radar data that corresponds to SM and surface roughness along the band and at an incidence angle of to. The gathering of such a massive amount of data was undertaken with the intention of enhancing the geometrical characterization of the soil structure through the application of a "fractional Brownian model." Over a few different spatial ranges, it was discovered that the soil profiles were "locally fractal." It has been discovered that there is a connection between the "shape of correlation function" and the "fractal dimensions," and this discovery has led to an improvement in the soil profiles that correspond to the root mean square (height and correlation length), which, when combined with the radar data, show a positive outcome.

According to an analysis done by Mozos et al. (Alvarez-Mozos et al., 2009), estimating the moisture content of the soil based on its surface roughness presents a significant challenge. As a result, they looked into conditions such as the "impact of roughness spatial variability" and the "temporal roughness variations" to determine how they affected the SM estimation. They used a variety of sensor configurations during the time period of "September 2004 to March 2005" to conduct research on both of these conditions. In the end, they came to the conclusion that these conditions have a significant impact on the estimation of SM, and that it is necessary to take care of them when estimating SM. To simulate interference patterns, Franco et al. (Franco et al., 2019) presented a method in which the soil surface roughness is directly calculated using. This method was presented by Franco. They have made the discovery that when the "notch" is positioned along the polarisation direction, the typical soil roughness is reduced to an extremely low value. When the roughness of the soil is reduced, the notch disappears, and a pattern with minimal interference can be seen close to the Brewster angle. The second order was utilised by Burkholder et al. (Voronovich, 1994) in order to investigate the temperature correction and brightness correction caused by the interface of a two-layer medium. They came to the conclusion that the surface roughness of a two-layer medium can either increase or decrease the brightness that is observed from shallower angles.

3. Measurement principles of soil moisture sensor

Dielectric method: The dielectric constant of a material can varies greatly depending on the material. The electromagnetic frequency, temperature, salinity, soil volumetric water content, ratio of bound water to total soil water content, soil density, soil particle shape, and form of moisture content are some of the factors that determine the dielectric constant of the soil. Due to the fact that the dielectric constant of water in soil is significantly higher than that of other substrates and air, it is primarily dependent on the amount of water that is present in the soil. Determining the soil's dielectric constant is therefore a viable alternative to the more traditional method of measuring the water content of the soil.

Resistance principle: The resistance between electrodes that have been inserted into the medium is measured by resistance-type moisture sensors in order to determine the level of

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moisture present in the medium. Because of the varying levels of moisture in the soil, its resistance value also varies. This causes a change in the current that flows between the electrodes of the sensor when it is inserted into the soil, which is then amplified and transformed into a form of direct current voltage. After that, a voltage-moisture curve that has been recalibrated can be used to estimate the amount of moisture present in the soil. In the past, this method of measuring soil moisture only required a single sensor; however, with the recent development of matrix sensors, this method can now accommodate multiple sensors.

Types of soil sensors

4. Methodology

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For the purpose of this study, the components take the shape of an Arduino Nano, a DHT22 sensor, a pH sensor, an LCD 16x2, and a power supply. The power supply on the device is responsible for supplying the entirety of the system. The temperature and humidity of the environment can be determined with the help of the DHT22 sensor. The pH sensor can also be used as a pH metre for soil. The results of measurements taken by the DHT22 sensor and the pH sensor will be displayed on the 16 x 2 LCD, and the LED will serve as an indicator [8-12]. The Arduino Nano microcontroller serves as a controller, receiver, and processor of data from the DHT22 sensor and the pH sensor. A block diagram illustrating the process of measuring the temperature, humidity, and pH of the soil was presented.

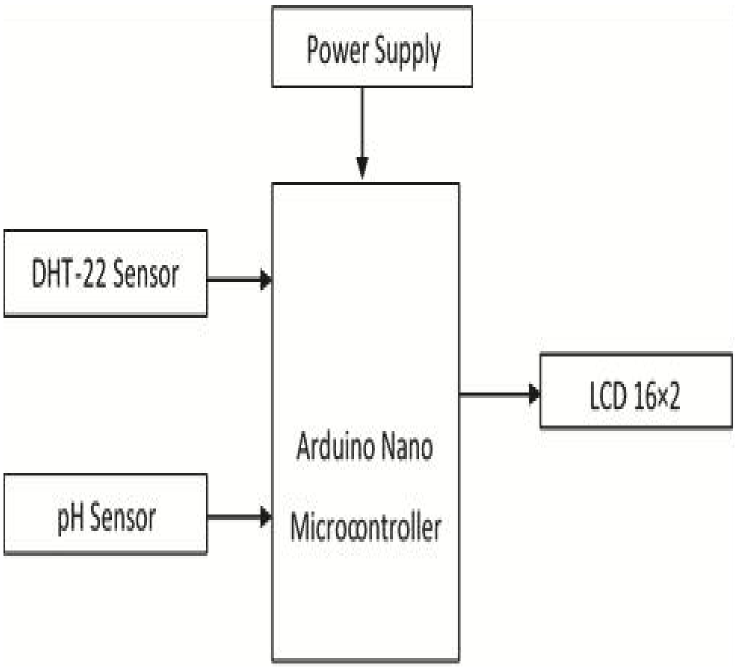

Figure 1: Block Diagram of Measurement System

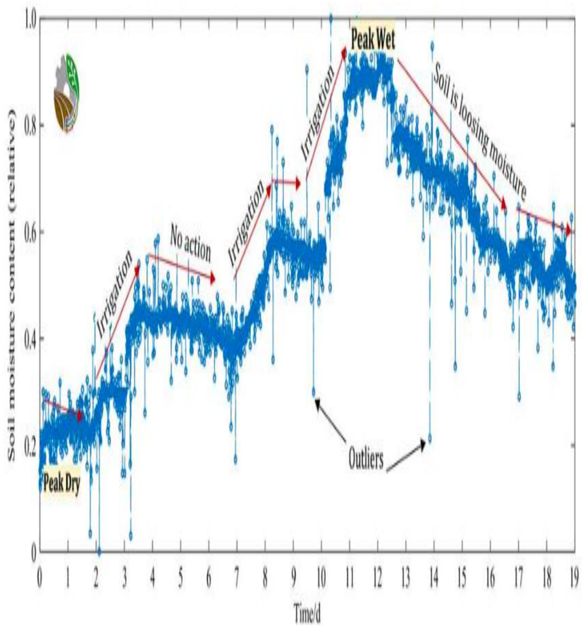

Figure 2: Output waveform

5. Conclusion and Future Scope

The monitoring system for the soil's moisture response is designed to be very easy to comprehend and work with. Farmers of any age can use it effectively without any difficulty. It is reprogrammable, so additional features can be added as needed. The moisture content of the crop is evaluated all the way down to the root zone. As a result, it can be used to test the level of moisture content in any crop. The sensor can be positioned horizontally in the soil at varying heights depending on the crop to determine how deeply the water has penetrated, or it can be positioned vertically in the soil to determine how deeply the water has penetrated. It is simple to use, so even farmers with little education should have no trouble mastering it. When the moisture is measured in the morning and in the evening, it is discovered that the moisture is linear up to 20 percent VWC (volumetric water content), and after that, the output voltage becomes almost constant. This is discovered after the moisture has been checked.

The design of a moisture sensor for the soil can be altered to accommodate the many different types of soil. It is possible to create a database. It is possible to use it to ascertain the kinds of acids, alkalis, or salts that are present in the ground. It is also possible to determine the salinity of soil by establishing a correlation between it and the output voltage. Zigbee and Bluetooth are two wireless communication protocols that can be utilised to send output data wirelessly and directly to the user. We are able to retrieve the values from the data base that is stored in the computer, which will allow us to determine the moisture holding capacity of the soil.

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