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Automated Soil Moisture Monitoring using Wireless Sensor Networks

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Abstract

In order to maximize the use of water for agricultural crops, an automated soil moisture monitoring system was created. A wirelessly dispersed network of soil-moisture and temperature sensors is employed in the system to monitor conditions in the root zone of the plants. In addition to these functions, a gateway device can manage the data collected by sensors, trigger actuators, and transmit data to a web application. A microcontroller-based gateway was built with an algorithm that was based on temperature and soil moisture threshold values for the purpose of managing the amount of water that was available. The electricity for the system came from photovoltaic panels, and it had a bidirectional communication connection that was built on an interface between cellular technology and the internet. This gave customers the ability to plan watering and analyse data via a web page. When compared to the conventional irrigation methods that are utilised in the agricultural zone, the automated system's test run on a field of sage crops resulted in water savings of up to 90 percent. The test lasted for 120 days. Since its implementation 18 months ago, the automated technology has been utilised effectively in all three of its designated places. Due to the low cost and energy independence of the gadget, it has the potential to be useful in places that have limited access to water and are located in remote areas.

1. Introduction

Improved agricultural production efficiency without influencing these numerous aspects is a core demand of agricultural modernisation, and precision agriculture (PA) addresses this essential need. The goal of farm automation technology is to improve object tracking and trajectory identification for agricultural items. The data that is monitored, recorded automatically, gathered simply and efficiently serves as the foundation for precision farming. But over the past few years, technology has become increasingly significant. Different autonomous vehicles from various fields of operation have recently entered the market, but all of these impressive products are commercially available and come at a significant cost to farmers (depending on their accuracy and functionality). All vehicle operations are fully autonomous, and all control routines depend on a central processing unit for coordination, which was created by numerous systems. However, these systems are expensive per unit because the design facility's processing unit is put under a lot of strain. The quantity of electronic components on agricultural equipment rises under regular field conditions, and controls as such as implement system controllers, variable rate planter controllers, and spray rate controllers interact with typical vehicle operation. As a consequence, every agricultural machinery now has a common communication connection. As a result, a new technique was required for agricultural autonomous vehicles, which classifies various solutions based on their accuracy and dependability and quantifies any auto-steering system level performance.

Given the fundamental necessity to feed the world's population, technology must be incorporated into the agricultural industry to, among other things, lessen the negative effects that crops have on the environment and promote resource conservation. One of the key elements in advancing the development of sustainable agriculture is efficient irrigation, particularly in arid and semi-arid areas where the biggest obstacles exist. There are three general categories into which irrigation techniques may be divided: drip irrigation, sprinkler irrigation, and gravity irrigation. The oldest and least effective approach for resource saving is the gravity irrigation system. However, sensing devices must be used to collect information such as soil moisture in order to determine the precise irrigation requirements of crops.

The idea of precision agriculture first gained traction in the USA in the 1980s. It is a management technique that enables decision-making to raise agricultural output and produce more sustainably. It is centered on managing crops by tracking the variability of the numerous elements that impact them and taking appropriate action. The soil where crops are grown may be monitored using Internet of Things (IoT) technology, allowing for better informed decision-making and efficient watering. The employment of drones to assist the network and control the application of pesticides to crops is one of these possibilities, in addition to the technological equipment already present in the fields. However, it is crucial to be able to precisely control soil moisture levels when performing crop monitoring tasks, particularly in situations where fruit trees are grown. Making ensuring the roots of a fruit tree obtain the proper amounts of moisture is essential for its growth. High humidity may encourage the growth of fungus in the roots and leaves, which can have an impact on productivity. However, the soil can crack if the moisture content is too low. resulting in the tree's death and shattered roots. This fact has a detrimental impact on plant growth, which in turn reduces plant yield. The high cost of the sensors and other technologies used in precision agriculture is one of its key downsides. Low-cost solutions must be made available in order to facilitate deployments for farmers who wish to employ technology extensively.

Various methodologies are utilised by the commercially available soil monitoring sensors in order to ascertain the amount of water that is contained within the ground. The gravimetric, tensiometric, neutronic, dielectric, gamma-ray attenuation, Wenner or resistive, and infrared light techniques are the most effective ways that are now used for estimating the amount of moisture that is present in the soil. When low-cost sensors are employed to evaluate soil moisture, conductivity-based sensors, which are typically based on the use of two electrodes, are typically utilised. Lack of dependability and durability are these sorts of sensors' two main drawbacks. On the one hand, the conductivity measurement may change even while the soil's water content is constant depending on the kind of soil and its salt concentration. On the other side, since the electrodes must be in touch with the ground, they may degrade quickly. To detect the moisture of the soil, inductive sensors are also used. To read the parameters, they do not, however, incorporate the system into a sensor node.

The network design should also be taken into account. Fields are often found in far-off places. It's possible that these places lack connection to the electrical grid and internet infrastructure. As a consequence of this, public address (PA) systems ought to incorporate some kind of energy harvesting, such as solar panels, and some elements of these networks ought to be taken into consideration when formulating a strategy for the deployment of sensing devices. Wireless communications have a number of advantages, one of which is that they eliminate the need for costly and difficult to build cabled networks across broad areas where equipment is utilised. But because of how the crops' foliage affects the signal, there is less coverage between the devices. In light of the crop type and field size, it is vital to choose the best deployment strategy for the targeted area. Additionally, the protocols that are currently in use might not offer all the functionalities needed for a specific crop and the resources in the area.

This proposal's hierarchical layer structure, where each layer includes a number of nodes that may alter their roles as needed, is one of its most distinguishing features. In other words, all actuator nodes and sensor nodes are wireless systems with the capacity to relay packets. If a node were to hypothetically fail, communications may still be diverted by other nodes in the same tier. If numerous nodes fail and one of them is still operational while being isolated, it may still be able to communicate via nodes on the higher or lower tier. These nodes would only send the packet to other nodes on the same layer as the isolated node. Establishing an alarm system based on keep-alive messages is handy for dealing with the failure of a sensor or actuator node. It is a daily chore that is periodically planned. Because irrigating a field is not regarded as a critical task, it is possible to work with a large periodicity. The system will treat a node as down if one or more nodes fail to reply to these queries. A low-cost method has to be created in order to assess the moisture levels in the soil's depths. Four coil-based sensor components that are evenly spaced along 60 cm make up this system. The coils are linked to a CPU module that is responsible for gathering the data and wirelessly transmitting it to the other nodes in its group. Finally, the actuator nodes will turn on or off the ditch gates or the drip irrigation based on the moisture values that the sensor nodes have gathered.

We refer to the quantity of water in the soil when we speak about moisture or soil humidity. The relative comparison between the dry soil mass and the moist soil mass—which is usually higher—is provided by the gravimetric analysis technique. The % moisture is calculated by multiplying the difference between these two numbers by the bulk of dry soil. Moisture will be 0% if there is no change. In the opposite situation, the soil moisture level will be 100% when the moistened soil mass doubles the dry one.

2. Literature Survey

In recent years, the implementation of Wireless Sensor Networks (WSNs) for soil moisture monitoring in precision agriculture has gained significant attention. This is primarily due to the need for accurate and timely soil moisture data to optimize irrigation, minimize water waste, and increase crop yield.

Wireless sensor networks are used in a unique system by Zheng Ma et al [1] to gather environmental data in agriculture. The system's goal is to provide farmers with the data they need to make informed choices regarding irrigation and other environmental parameters by

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continuously monitoring temperature, humidity, and soil moisture levels. The system's design and execution are described by the authors, who also provide experimental data proving the system's efficacy.

The wireless temperature monitoring system described by Zhu Yao-lin et al [2] is based on the nRF24L01 module. The system is designed to monitor temperature concurrently at many locations and send the information wirelessly to a central receiver. The system's design and implementation are described in depth by the authors, who also offer experimental findings that show the system's precision and dependability.

A review of field tools for tracking soil water content is presented by Rafael Muoz-Carpena et al [3]. The pros and cons of different gadgets, such as neutron probes, time domain reflectometry, and capacitance sensors, are discussed by the writers. They also provide suggestions for choosing the best gadget for certain uses.

Using the CC2530 module, a temperature and humidity monitoring system is described by Xu Bo et al [4]. Real-time temperature and humidity measurements are made possible by the system, which wirelessly sends the information to a central receiver. The system's design and implementation are described in depth by the authors, who also offer experimental findings that show the system's precision and dependability.

An assessment of autonomously guided agricultural vehicles is provided in by Rovira-Mas, Francisco et al [5]. The advantages of employing these vehicles, such as improved efficiency and lower labor costs, are discussed by the writers. They also talk about the difficulties in putting these cars into use, including as technical constraints and security issues. Future research in this area is suggested by the authors.

An overview of robotic agriculture is provided by authors in [6]. The advantages of deploying autonomous robotic service units for a variety of agricultural jobs, such as planting, harvesting, and crop monitoring, are discussed in the article.

The use of unmanned aerial vehicles (UAVs) and wireless sensor networks (WSNs) for agricultural applications is the topic of a paper by Fausto Costa et al [7] published in the IEEE. The article explains the applications of these technologies, including yield prediction and crop monitoring.

P. Satyanarayana et al [8] address the creation of a low-cost mobile phone-based irrigation system utilizing an Arm processor. The system's capabilities for monitoring soil moisture and managing irrigation are discussed in the article.

The application of WSNs for real-time monitoring of agri-parameters is discussed by Sulakhe Vinayak. V et al [9]. The system's use for precision agriculture, including crop monitoring and irrigation management, is described in the article.

The creation of an embedded pH data gathering and recording system is discussed by V. Ramya et al [10]. The system's use for soil analysis and crop monitoring is described in the article.

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A study by Lloret et al. [11] demonstrated the successful deployment of a WSN for soil moisture monitoring, which included a combination of sensors, data acquisition systems, and communication devices. This deployment allowed for real-time monitoring and improved decision-making regarding irrigation management. Similarly, Hamouda et al [12] proposed a variable sampling interval technique for energy-efficient heterogeneous precision agriculture using WSNs. This approach aimed to optimize the balance between energy consumption and data accuracy, demonstrating the potential for more sustainable and efficient agricultural practices.

In addition to WSNs, other technologies have been explored for soil moisture mapping. Badewa et al. [13] conducted a study using multi-frequency and multi-coil electromagnetic induction sensors to map soil moisture in managed Podzols. This research highlighted the potential of using advanced sensing techniques for more accurate and detailed soil moisture mapping.

Srbinovska et al. [14] focused on environmental parameters monitoring using WSNs for precision agriculture. The study showcased the effectiveness of WSNs in monitoring various parameters, such as temperature, humidity, and soil moisture, thus contributing to the optimization of agricultural practices and resource management.

Despite the advances in agricultural monitoring systems, Fritz et al. [15] identified existing gaps and compared different global agricultural monitoring systems. The authors emphasized the need for improved data quality, increased spatial resolution, and better integration of various data sources to enhance the overall performance of these systems.

3. Proposed Model

A wireless network that does not have any physical infrastructure and that is formed ad hoc utilising a large number of wireless sensors to monitor system, physical, or environmental parameters is referred to as a "Wireless Sensor Network" (WSN). This word is abbreviated as "WSN." In a WSN, the sensor nodes are equipped with a central processing unit that is used to control and monitor the environment of a particular location. They have a connection to the Base Station, which acts as the central processing hub for the WSN System. A WSN system's base station connects to the Internet to exchange data.

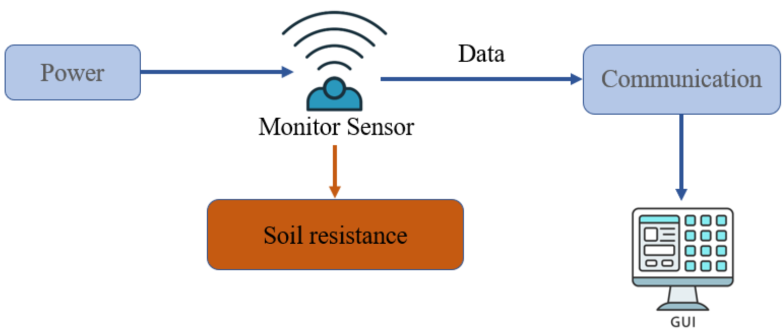

Figure1. Automated Soil Moisture Monitoring using Wireless Sensor Networks

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Soil moisture sensors have developed into a crucial instrument in contemporary agriculture since precise irrigation techniques have a direct impact on harvest numbers. There are many different kinds of sensors for measuring soil moisture, but contemporary satellite sensors are in a class of their own since they can monitor ground moisture levels remotely without having to be installed. In many aspects of precision agriculture and associated sectors, we may utilize the data collected by soil moisture sensor systems to make smarter judgments.

Figure 2. Real time Wireless Sensor for soil moisture monitoring

One of the key components of smart farming is the use of soil moisture sensors. They are always changing to make them more user-friendly. Modern smart soil moisture sensors may send data wirelessly, be installed at different depths, and upload readings immediately to a GIS database, removing the need for human data collecting. This is in contrast to earlier, more laborious approaches.

Sensors are also being portable; thus they are not only confined to being stationary. With portable devices as opposed to stationary ones, data can be collected from any location and depth. The varieties of soil moisture sensors available depend on the underlying technology. implanted in the ground to check on the condition of the root zone; Unmanned aerial vehicle (UAV) airborne data retrieval, a rare method in soil moisture mapping; using a satellite to assess the situation from orbit. They help save money, don't need labour-intensive installations, and don't obstruct field operations. Maintaining enough water saturation is the farmer's first priority since it is essential for plant growth. Lack of irrigation causes fading because plants need all of their energy to absorb little water via their roots, leaving insufficient energy for the crop to develop and produce well. However, enough moisture enables the plants to survive frequent stressors, remain healthy, and develop to their full potential. On the other side, over watering results in root rot, obstructs the oxygen flow, and ultimately kills the plant. As can be seen, without maintaining steady water content levels, things may go anyway. Due to the efficiency, dependability, and affordability of online agricultural apps with soil moisture characteristics, soil moisture sensors for agriculture are essential farming instruments. When compared to the amount of time and effort needed to use them and the quantity and quality of data they can produce, satellite remote sensors are an excellent value. They enable farmers to more skilfully control risks associated with water shortage and excess, which enhances plant development. This is made possible by their incorporation into regular agricultural practices.

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Table 1: Components used

COMPONENTS	SPECIFICATION
Microcontroller	PIC24FJ64GB004
Soil Moisture Sensor	VH400
Panel Solar	MPT4.8-75
Transceiver	XBee Pro S2
Soil Temperature Sensor	DS1822
Batteries	AA 2000 mAh Ni-MH
Voltage, Regulators, Connectors, capacitors, resistors etc	

4. Result

Here we have taken data gathered from WSN (Wireless Sensor Network) from soil moisture retention and we can see graphical representation going up and down due to dependency on water irrigation system.

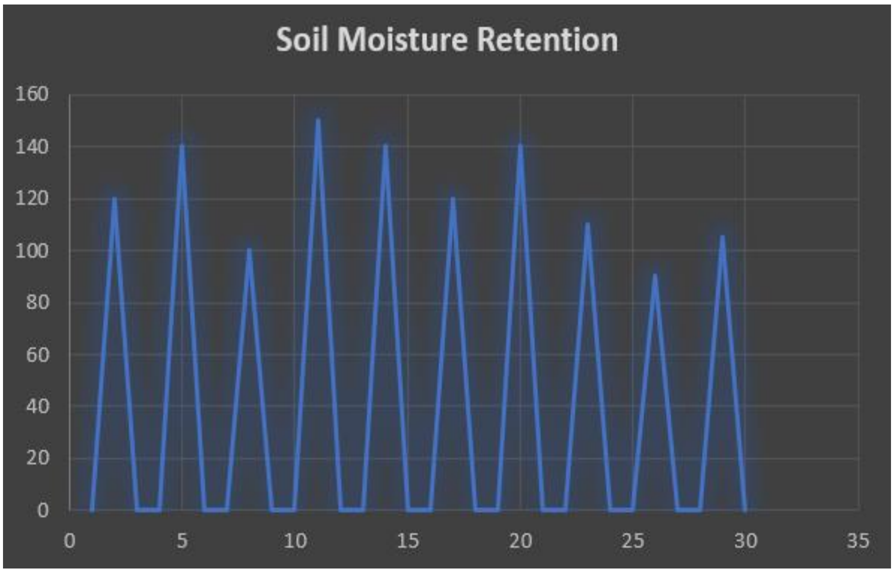

Figure 4. Soil moisture retention Graph

5. Conclusion

It was discovered that the automated irrigation system put in place was practical and economical for maximizing water resources for agricultural productivity. Because this method of irrigation makes it possible to cultivate in dry areas, it contributes to a more sustainable environment. Because of the creation of the automated irrigation system, it was discovered that a lower volume of water may be used to produce the same amount of new biomass. When it comes to organic crops and other agricultural goods that are grown in geographically isolated areas where it would be expensive to make an investment in an electric power supply, the utilisation of solar power in this irrigation system is not only current but also significantly vital. The irrigation system is easy to maintain and may be adapted to meet the requirements of a number of different crop types. Because it is constructed in a modular fashion, the automatic

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watering system can have its capacity increased to service open fields or larger greenhouses. In addition, it is simple to install other apps, such as monitoring the temperature while producing compost, which is one of the applications. A potent idea for a decision-making device that can be modified to diverse farming settings is offered by the duplex communication system that is handled by the Internet. In addition, the Internet connection makes it possible to monitor the situation via mobile phones, including portable phones.

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