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Monitoring of Soil Moisture in Tomato Field Using Internet of Things

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***Abstract**: Ever since the dawn of time, agriculture has been emphasized as having a significant impact on people's lives. Modern technology, which has enhanced the variety of technologies to raise the standard of living and streamline daily operations, is a tool that has been employed to create novel methods of life to meet human demands as the population grows. Internet of Things (IoT) is one of the popular applications today, but it adds a new dimension to intelligent farming and agriculture by making it convenient to connect farms and agricultural bases that are conveniently located in rural or remote locations using sensors and actuators. Robotics and chemical technologies are not the only ones that may be used to improve and modernize people's lives. We suggest an IoT network architecture that comprises Wi-Fi-based long-distance networks that may be used for remote soil moisture monitoring in greenhouse tomato crops. The suggested approach was actually applied, proving the potential of developing IoT-based systems in the suggested location. The soil moisture based IoT prototype includes the sensing unit, connectivity, data processing, and data processing. The sensing unit, communication, data processing, and data processing have all been incorporated as a part of the soil moisture-based IoT prototype. According to the research, the suggested soil moisture monitoring technology evaluates soil moisture regulation in addition to showing real-time soil moisture data. It also reduces unnecessary water use, frees up farmers' valuable time, and improves farming systems compared to current farming systems.*

Keywords—IoT, Cloud, IFTTT, Mobile application, Node MCU, Soil Moisture sensor

1. INTRODUCTION

Wireless sensing technology and the Internet-of-Things (IoT) solution reduces data collection errors, improve the accuracy of remote monitoring, and provide a more significant assessment of the micro-environment through dynamic assessment. Resulting of technological progress, device size reduction, and versatility, machine learning and sensors' use is becoming possible in virtually every area of life. A sensor is a system with the ability to calculate and translate physical attributes into signals for the observer [8]. In addition to particular agricultural applications, including soil preparation, crop status, irrigation, and insect and pest detection, sensors are used in every facet of life; sensors are utilized [3]. These gadgets range in complexity from straightforward domestic objects to complex industrial machinery.

Smart water management for irrigation technology is essential in agriculture for increasing crop productivity, reducing costs, and improving environmental sustainability. The increased use of technology makes it possible to give plants the exact amount of water they require. The Internet of Things (IoT) is an obvious choice for smart irrigation applications even though it has not yet fully integrated the numerous technologies required to operate without a hitch in practice [7]. The impact of linked gadgets on our lives has been felt in every area, from health and well-being to home automation, automotive and logistics, smart cities, and industrial IoT; thanks to the growing adoption of the IoT, it's only natural´ that IoT, connected devices, and automation will naturally make their way into agriculture, substantially enhancing almost all of it (Neha and Vishal, 2019) said that Wireless sensor network (WSN) for irrigation management has proved out to be helpful for water savings [11], livestock Intelligent pest control and Smart greenhouses.

2. BACKGROUND STUDY

Every area of our life has changed, resulting from the IoT's widespread acceptance, including our health and wellbeing, home automation, transportation and logistics, smart cities, and industrial IoT. Therefore, it stands to reason that the Internet of Things (IoT), connected gadgets, and automation will eventually make their way into agriculture, significantly enhancing practically all of it. Water savings have been demonstrated to occur when irrigation is controlled using a wireless sensor network (WSN), according to Neha and Vishal (2019). [11], One could continue to rely on horses and ploughs without the presence of physical equipment and equipment advancements in a time when self-driving automobiles, virtual reality, and the ability to remotely monitor items in your field via a smart smartphone are not futuristic concepts but rather everyday occurrences. Farming's new present and future are being defined by the Internet of Things. Positive effects of automation are being seen in the sector's overall growth. The following tasks have become simpler with the introduction of smart farming solutions: real-time field monitoring, real-time livestock monitoring, water conservation through smart irrigation, remote crop management, and increased crop production. Smart greenhouse design and effective pest control [3]. IoT technology enables farming in small spaces with up to a 300 per cent yield boost, cuts water use by 90%, and saves hundreds of hours that would otherwise be spent manually monitoring the farm. This is done through irrigation automation and remote and real-time monitoring of the farm via our mobile phone application.

To design an irrigation system that works effectively, it is required to evaluate the data on soil moisture. Real-time data analysis has so far demonstrated that the Internet of Things is tremendously advantageous [14].

On the other side, Zanzibar has a young, small, and rapidly growing population. Zanzibar had a total population of 1,303,568 at the most recent census in 2012, with a consistent yearly growth rate of 3.1%. Males make up the remaining 49% of the population, with females making up 51% of it. The population of Zanzibar is primarily young (68% rural) and rural (MKUZA II; 2010). the majority of the labor force is concentrated in rural areas (68%), and most of the major agricultural operations are carried out by young people [15].

Traditional and primitive farming techniques are used in Tanzanian agriculture, particularly in Zanzibar. People rely on their own initiative to advance affairs, and the volume of output is dependent upon their efforts; their agricultural practice does not employ any computerized equipment or technology. The use of ICT-based and IoT-based scenarios in the farming process is not operated in developed countries like China, Korea, Singapore, and others that rely on modern tools like tractors, agricultural drones, and easily accessible modern computerized tools in their farming operations.

If nations adopt, invest, and put acceptable technology into practice, they will have the ability to sustain growth and compete. The best opportunity for streamlining agricultural operations, boosting economic growth, ensuring proper water use, preserving soil fertility in the field, and eradicating poverty across the continent is presented by the majority of African countries' strategic adoption of IoT sensor technology in the agricultural sector.

3. LITERATURE REVIEW

3.1 Internet of Things (IoT)

The term "Internet of Things" (IoT) refers to a network type that allows anything to be connected to the internet, based on predetermined protocols, using information sensing equipment to carry out information exchange and communications in order to achieve intelligent recognition, positioning, tracing, monitoring, and administration [12]. Cloud computing and IoT have the ability to technically enhance established methods based on plant signals, water balance sensors, or soil moisture sensors. The IoT connects physical objects (or "things") to the Internet by using low-power network connectivity with built-in sensors [21]. The internet is connected to a massive number of embedded devices (things). Regularly, these interconnected devices send sensor data to cloud storage and cloud computing resources, where it is processed and analyzed to produce insightful data, as depicted in the figure 1 below. This trend is being aided by low-cost cloud computing power and greater device connectivity. Environmental monitoring and control, health monitoring, vehicle fleet monitoring, industrial monitoring and control, and home automation are just a few of the vertical applications for IoT systems [18]. Through various techniques and applications, IoT has progressively brought about many technological advances in our daily lives that contribute to making our lives easier, and more comfortable [9].

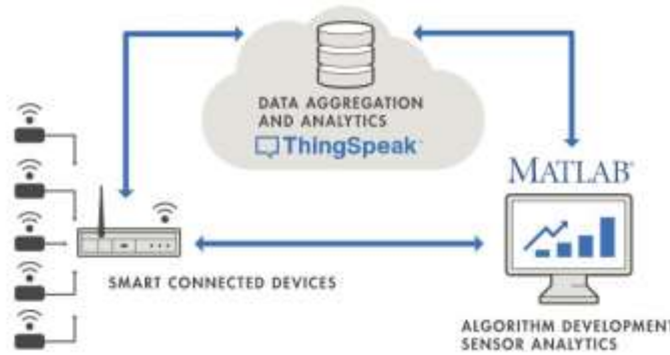

Fig. 1. Meaning of IoT (Adopted from thingspeak.com)

3.2 Soil Moisture

Precipitation (rainfall), temperature, humidity, and soil type all have a significant impact on how well water is captured and retained in the soil. Simply said, your soil's dryness or moisture content can both be used interchangeably [2]. Depending on the technology utilized, there are two different types of soil moisture sensors: 1) Volumetric water content sensors; and 2) sensors that, when implanted into the soil profile, measure soil tension. The amount of water in the soil can be determined or monitored using soil moisture sensors. These sensors can also be stationary or portable probes. In contrast to permanent sensors, which are placed in the field at predetermined depths and places, portable soil moisture probes can monitor soil moisture in a variety of locations [19].

3.3 Tomato Plant

The herbaceous tomato plant can grow to a height of 1-3 meters and has a weak, woody stem. It is usually recognized as "Protected Food." Each 100g of it has 31 mg of vitamin C. The cultivated varieties of the yellow-colored blossoms range in size from cherry tomatoes, which have a diameter of approximately 1-2 cm, to beefsteak tomatoes, which have a diameter of about 10 cm or more. Around the world, 700 different varieties of tomatoes are cultivated. Due to its short

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growing season and great output, it is acknowledged as an important commercial and dietary vegetable crop. As a result, the area under its cultivation is expanding daily [13].

3.4 Irrigation System in Agriculture

The two to three major ways that farmers and ranchers raise their crops using agricultural water are irrigation and rain fed agriculture. Using a direct downpour to irrigate soil organically is a practice known as "rain-fed farming". Relying on rain reduces the risk of contaminated food products, but it increases the risk of water shortages in the event of decreased rain. Using water artificially, on the other hand, raises the danger of contamination.

Various tube, pump, and spraying methods artificially apply water to the soil. In regions with erratic rainfall, dry spells, or a threat of drought, irrigation is frequently used. Irrigation systems come in a wide variety of designs, and the water is distributed evenly across the entire area. Surface water from rivers, lakes, or reservoirs, as well as desalinated or treated sewage water, are all possible sources of irrigation water. Consequently, to reduce the likelihood of pollution, it is essential for farmers to protect their agricultural water source [4].

3.5 NodeMCU (ESP8266)

Based on the ESP8266, a low-cost System-on-a-Chip, the NodeMCU (Node Microcontroller Unit) is an open-source software and hardware development environment (SoC). The ESP8266 Wi-Fi Module allows any microcontroller to connect to a Wi-Fi network because it is a self-contained SOC with an integrated TCP/IP protocol stack. The NodeMCU makes it feasible to build computers with greater sensing and control capabilities than desktop computers. This open-source physical computing platform is comprised of a software development environment and a basic microcontroller board [6].

It can manage I/O by using an Arduino microcontroller. On the ESP8266 12-E chip, there are 17 GPIO (General Purpose Input and Output) pins. The Espressif Systems ESP8266 is equipped with all the necessary parts of a contemporary computer, such as a CPU, RAM, networking (Wi-Fi), as well as a current operating system and SDK. The ESP8266 is a high-integration wireless SoC with unmatched potential for integrating Wi-Fi capabilities into our system or functioning as an independent application with low costs and little physical space requirements. Figure 2 represent the actual module for this research.

Fig. 2. NodeMCU (ESP8266)

3.6 IoT-Based Sensors for Smart Greenhouses

There are numerous IoT-based sensors for smart greenhouses, including ones that measure soil temperature, humidity, plant development and temperature, pH and moisture sensors, solar radiation, atmospheric pressure, wind speed, and CO2 (and other gas) sensors and electromagnetic [5]. The technique was also proven useful in measuring real-time plant physiology, including a plant's vegetative index, nutritional requirements, electrical conductivity, and magnetic susceptibility and conductivity (quad-phase) [5].

4. PROPOSED PROBLEM STATEMENT

Farmers have been making a lot of effort to water their tomato fields (Greenhouse) using their local tools, but they encounter many difficulties in the process. For example, they waste time waiting for the irrigation time in the field, water the plants with the incorrect amount of water, and water them at the wrong time, all of which reduce the effectiveness of plant growth.

To grow tomatoes, people have been employing greenhouses, but they have had difficulty determining when to irrigate their fields. From this vantage point, it motivates us to carry out studies utilizing the Internet of Things to track soil moisture and alert farmers when to water their tomato fields; this could be the most convincing method to persuade Zanzibarians to implement, use, and benefit from the IoT with excellent plant production, particularly tomatoes.

5. IMPLEMENTATION

The system developed for the investigation will involve gadgets. The activities are carried out using both hardware and software, and the crucial parts are a personal computer, the Arduino open-source software, a NodeMCU (esp8266), a soil moisture sensor (FC 28), a network administrator, and embedded C and libraries. The machine's brain is the NodeMCU or Arduino microcontroller, as depicted in figure3. Employing moisture probes inserted into the soil at the plant root zone, the soil moisture monitoring system was created to detect the moisture level every fifteen seconds by indirectly using the water characteristics in the soil. As a result, the device alerts the farmer that the tomato plants require water. When necessary, the soil moisture sensor monitors soil conductivity at various depths. It was used to start and startle events throughout the experiment since dry dirt is less conductive than wet dirt. A number of voltage readings and the voltage generated by the soil moisture probe were compared to it. (Determine a threshold value for the clay loam soil type employed in this experiment) with the compared output being high only when the soil condition becomes dry. Voltage signal collection was configured on the NodeMCU (corresponding to soil moisture levels) [10].

5.1 Soil Moisture Monitoring Algorithm

As shown in Fig 3, it is possible to automate soil moisture monitoring using sensors, a microcontroller, a Wi-Fi module, and an Android application. The inexpensive soil moisture sensor constantly monitors the land. The sensors are wired to the NodeMCU board. The prototype will review the information gathered and compare it to the moisture threshold values. An alert is activated and issued if the soil moisture is below the threshold value. The sensors are wired to the NodeMCU. Thanks to the hardware's Wi-Fi connection capabilities, the user can view the data via his mobile device, which runs an Android application that can get sensor data from the NodeMCU via the Wi-Fi module. When a particular level of soil moisture content is reached, the user can set the alarm to sound. The system instructs the user to maintain the threshold value based on the anticipated pattern of soil moisture and precipitation data. With the use of a trigger and a responsive web-based interface, the web service controls the node for real-time monitoring. This experiment used a Wi-Fi module to transmit the data to the server. Using Wi-Fi or a mobile data connection module, the data can be transmitted from the gateway node to the server.

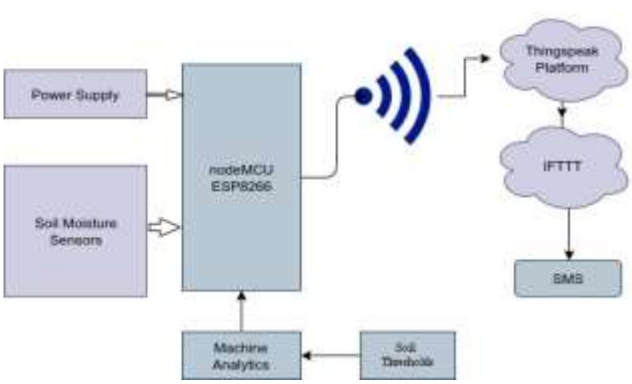

Fig. 3. Block diagram of system architecture

5.2 Design of soil moisture algorithm

Figure 4 displays the flowchart that illustrates the general operation of the setup. The information is gathered by the system upon system startup and sent to the cloud platform (Thingspeak) along with information from the soil moisture sensor and microcontroller NodeMCU. The Thingspeak cloud platform compares the soil moisture data to the threshold value set in relation to the plant using observations. The observation will be done by tracking the values and recording them. It will monitor the soil moisture levels around the tomato plants. If the soil moisture content drops below a predetermined threshold, the farmer will be notified that the tomato field needs watering. If not, the system will keep testing until the moisture falls below the predetermined level.

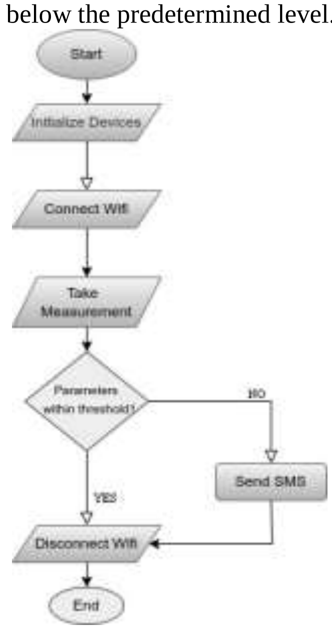

Fig. 4. Flow chart of working soil moisture system

5.3 Sampling techniques

It is a process of choosing a number of people or things from a population such that the chosen group contains elements representative characteristics found in the entire group. Additionally, it contains details on farmers' awareness of IoT in agriculture, their daily routines, and their thoughts on the implementation of the prototype in their setting; a questionnaire with a sample size of n=45 respondents was given using Google Form. Dunga Kiembeni (Zanzibar) was sampled based on the agricultural area/scheme and exclusively on the area of greenhouses (at the coordination point -
6.156706, 39.351306).

6. Deployment Process

Step I: Assembling the sensors, NodeMCU microcontroller board, and power source, these components are connected using jumper wires which are connected by an IoT specialist with great knowledge

6.1 Prototype

Before investing time and money in development, create a prototype to test your ideas and explain to others the reasoning behind a feature or the overall design concept [20]. A prototype low-fidelity to high-fidelity paper sketches to a tool that directs people to a fully functional website after they click through a small bit of content (high-fidelity). The prototype is powered by a desktop or laptop computer running the Linux operating system. The steps below are used to set up the proposed prototype: Assembling the sensors and NodeMCU with the Arduino expansion board, I presented the innovative soil moisture monitoring modelling infrastructure in figure 5 which can be implemented in the agricultural process and applications, which includes: integrated IoT applications between devices with the cloud platform, their deployment

Fig. 5. Implementing of the prototype in planted trees

7. DATA COLLECTION

In the course of the experiment, data from sensors are retrieved and made available for analysis and decision making. In the field, the sensors are set up on the surface. The stations regularly document spores; in order to gather vital information for sound decision-making, sensors and other digital technologies are used in agriculture. For basic agricultural monitoring, sensors acquire information from the field [17]. However, the majority of research begins with the collection of raw data utilizing wireless sensor network based systems, followed by evaluation. The collected data is loaded into the cloud, where it is processed more rapidly, cheaply, with certainty and efficiency [16].
In order to get data directly from the field to acquire the expected/desired findings, IoT-based instruments like soil moisture sensors and NodeMCU will be employed. The integration of NodeMCU with other IoT devices for alerts and moisture level monitoring will be done on the client side using a module that comprises a web application and SMS [1].

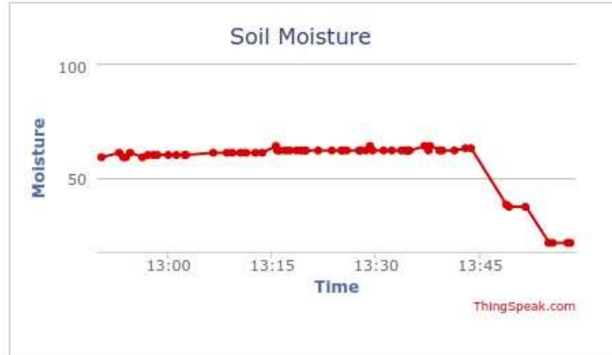

Fig. 6. The soil moisture vs time graph during the day of testing the system

The tomato plant's soil moisture value on the testing day after the installation of the suggested prototype is shown in figure 6. It is clear that the level of soil moisture could be maintained for a while, but when the temperature rose in the middle of the day, the level of soil moisture drastically dropped.

8. RESULT, DISCUSSION AND OBSERVATION

The results of this study allow us to draw the conclusion that IoT applications can be employed in any area of agriculture because they present fewer implementation issues. In the study, different gadgets and technologies were linked together to build an embedded system that gathered real-time data in the field. The system prototype is affordable as it is based on open standard technology. The auto mode makes it a smart system, and it may be further modified for conditions unique to particular applications. In the future, we aim to lower the system's price and conduct a water-saving study based on the proposed method with several nodes. A nodeMCU Microcontroller, soil moisture sensors, and an online platform (Thingspeak and IFTTT) for data and automation were all part of the systems.
To better inform stakeholders about environmental conditions, the collected data was analyzed, saved, and shown using graphs and charts. It was evident from the automated IoT procedure used to alert farmers to the demand for water in the field in the Zanzibar farming setting, particularly in the greenhouse, that this reduced human participation and increased efficiency. The primary programs that are currently available for usage in scenarios like these were outlined, with an emphasis on assessing the benefits and drawbacks of existing approaches to irrigation scheduling.
The examination of alternative technologies and methodologies was prompted by the shortage of water due to climate change and the need to protect soil and groundwater while maintaining yield and product quality. Due to a growing dependency on water resources from other economic activities, irrigation practices for vegetable crops will need to change in order to maintain a suitable sub-optimal plant water status.

9. CONCLUSION

The results of this study are essential for Tanzanian small, medium, and large-scale farmers as well as decision-makers in those fields. One of the issues is that many rural areas lack suitable network connections, and another is that IoT devices are widely available across the country. Many farmers do not take into account the efficient application of current and accessible technology to promote crop production. As a result of all of this, people became aware of the technology that was accessible and some of the limitations of the physical infrastructure of the land.

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