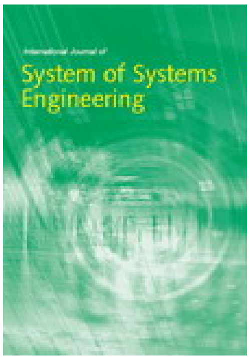

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Performance analysis of internet of things-enabled WSN for agriculture

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Abstract: An increasing number of sensors and other intelligent devices are making the internet of things (IoT) a topic of interest for the simplicity with which information and communication may be obtained. Wireless sensor networks (WSNs) are crucial to the IoT due to their low power consumption and high data interchange capacity. Agricultural precision systems focus on developing effective, economical, and dependable monitoring and actuation technologies. To do this, it makes use of several different technologies, including wireless sensor networks, sensor devices, the IoT, and data analysis. The proposed study incorporates a wide range of technologies to prototype a precision agriculture system for medium and small agricultural plants, focusing on efficient energy management with self-charging capabilities and a low-cost strategy. A cloud-connected autonomous system with multiple sensor nodes is constructed. Smart data processing and analysis can improve forecasting, sensor management, and decision-making. The suggested system monitors soil moisture, humidity, and temperature using wireless sensor networks and the IoT.

Keywords: IoT; internet of things; power consumption; precision agriculture; energy management; WSNs; wireless sensor networks.

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Reeba Korah holds a PhD from Anna University, Chennai. She has a vast experience of over 3 decades in the field of engineering academics, administration and active research. She is an alumnus of Marathwada University, Maharashtra and Anna University, Chennai. Her expertise includes VLSI design, image/video processing, and wireless sensor networks. She is published 75 papers in international journals and conference proceedings. She has authored five books of electronics engineering. She's supervised

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1 Introduction

Precision agriculture has inspired numerous ideas, including the use of cutting-edge technology to construct more robust and efficient foundations upon which agricultural businesses might be operated. Nowadays, a lot of gear has fancy sensors built in, so you can talk to it and engage with it right away. Massive amounts of data may be gathered and analysed using surprisingly simple and inexpensive hardware with the aid of these technologies and infrastructures. The IoT aims to connect these devices so that they may be utilised in novel ways to accomplish extraordinary feats. The IoT idea, when applied to already existing technology, allows for a wide range of applications in the field of agricultural monitoring. Wireless sensor networks (WSNs), broad node-to-node communication, constant monitoring of the environment, effective use of energy and water in building an autonomous system, and limiting the cost of the system all fall under this category.

The WSN's design and construction are shown in great detail in Figure 1. The sensor node incorporates connectivity and processing power. During the linking process, a short-range wireless network may be set up as a multi-hop network. Wireless sensor networks are used in precision agriculture to monitor crop growth, learn more about the agricultural environment, and advance the state of the art. Further, WSNs are low-cost, simple to set up, and power-efficient. It continues to function to a high quality for a long time and is versatile enough to accommodate different farming methods. There is potential for the development of a wide range of data acquisition algorithms that share aspects with modern agriculture, allowing for the continuous expansion of precision agricultural operations and substantially reducing the time spent on data collecting. Outside of its basic function of improving precision agriculture and increasing agricultural production, the WSN has numerous other applications in agriculture, as shown in Figure 2. Soil nutrient data might be used to make predictions about crop health and the quality of agricultural output. Monitoring weather conditions (including temperature and humidity) and soil moisture levels may also help with future irrigation scheduling (Vaishali et al., 2017).

Recent WSN studies have targeted agriculture intending to improve upon established farming practises. The miniaturisation and decreasing cost of MEMS technology has made previously inaccessible sensors practical. Due to their scalability, compact nodes, and inherent benefits of self-organisation, WSNs are a great alternative for automating agricultural procedures. The development of WSN-based applications for smart agriculture has considerable obstacles due to the limitations of WSNs in processing power, memory, and battery life. Finding the root reasons for growing energy consumption is a prerequisite for developing effective remedies (Saraf et al., 2017).

Figure 1 Prototype of a smart farm (see online version for colours)

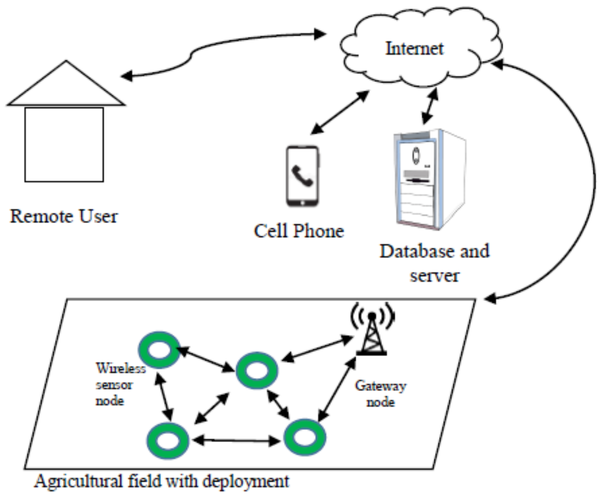
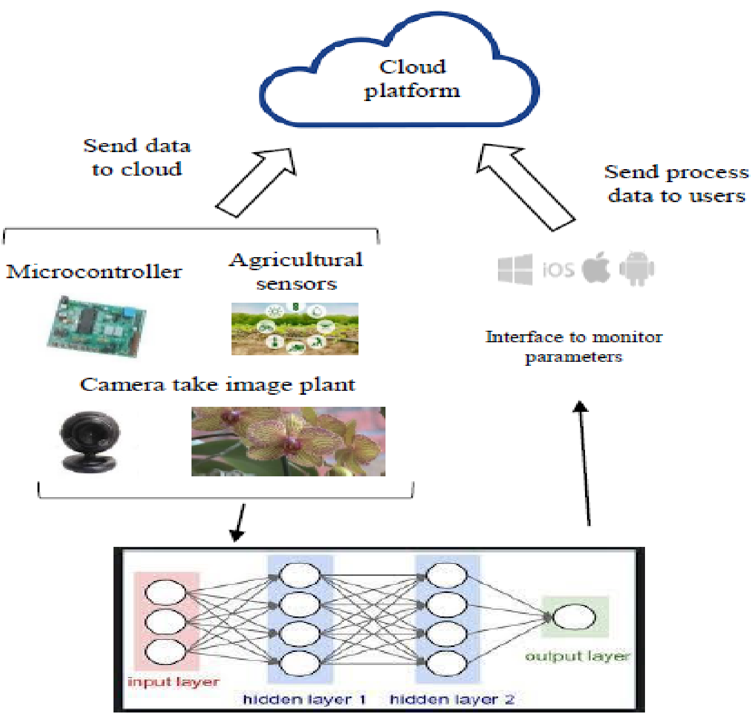


Figure 2 The neural network to process the image (see online version for colours)



Wireless sensor networks and the incorporation of their capabilities into industrial workflows are complementary in terms of what they can do. How a WSN is constructed to make up for the shortcomings of the traditional cable system determines its deploy ability, range, cost, stability, mobile support, and other aspects. While a larger network (with more nodes) will produce more reliable aggregate data, lowering the bar for individual node precision, deploying a large number of nodes does raise questions about the network's security and stability. The resilience of the underlying network can now better tolerate unexpected events. Second, unlike wired networks, a self-organised network can be more adaptable and have lower line costs. In conclusion, the adaptable nature of a data-centric WSN means that it may offer layered and nuanced access to data. This is why WSNs are showing great promise for the intelligent acquisition of data required for precision agriculture, and why they are being used in a wide range of monitoring domains, from hydrology and industry to the military and the smart home (Vijayalakshmi et al., 2019).

1.1 Intelligent farming IoT applications

Smarter and more intelligent production, household life, public transportation, and city planning have all been made possible by IOTs. Precision agriculture, also known as smart farming, has emerged as a result of the increased use of IoT devices in the agricultural sector (Maniyath et al., 2018). It's also possible to do this. Industry, the home, transportation, and city planning are just a few of the areas that have benefited from IOTs' widespread use. Precision agriculture, also known as smart farming, was developed as a result of the broad use of IoT devices in the agricultural sector. There's also this alternative.

1 IOT crop management

2 Smart irrigation system.

1.1.1 Goals

- To create a low-cost smart power auto irrigation system that can be used in irrigation.
- To develop and implement a system that comprises a variety of sensors to determine the field's real-time state both online and offline.
- To create a system that uses the least amount of electricity to run a WSN node.
- To evaluate sensor data in order to forecast future crop temperatures, humidity, and soil moisture (Kanade and Prasad, 2021).

2 Literature review

Applying the IoT through WSNs for precision farming has been discussed at length by several authors, and this analysis will focus on their perspectives. For fields that can be subdivided into a range of heterogeneous agriculture and farm areas, Hamouda et al. (2019) provide an ideal heterogeneous irrigation system based on a WSN that is deployed for irrigation. System position and agricultural data are processed in real-time by an enlarged Kalman filter (EKF). The information collected by all wireless sensors can be filtered using EKF and then communicated to the IoT (Sanjeevi et al., 2020).

To maximise productivity while reducing costs, the agricultural sector needs a cloud-based decision-making and support system (Usha et al., 2019). Predictions of weather and environmental conditions are made with the help of a decision-making and supporting system, and related data is saved in the cloud with the help of the IoT. Using the IoT, the proposed decision-making and supporting system may access all sensor data collected, resulting in more accurate weather forecasts.

Proposed an IoT-based smart agricultural farming system, with the Indian government providing around 73% of the money and the system directly employing the workforce (Das et al., 2018). Many factors contribute to a decline in crop and post-crop output, which in turn generates severe financial hardship for farmers and national and local governments. Precision agricultural technology employing the IoT is presented as a means to lessen the amount of crop output that is lost during harvest. Information gathered by a WSN is managed with the help of Raspberry Pi technology and a wide range of field sensors.

Have suggested a technique for data aggregation via the use of a duty cycling algorithm, intending to boost agricultural output through real-time monitoring and management of plant field measurements (Saraf et al., 2017).

Drones may collect data in the field by carrying wireless sensors that detect things like temperature, soil, humidity, and air quality (Sullca et al., 2019). Drones can also be equipped with surveillance cameras. Every wireless sensor's readings might be gathered at the BS and sent on to the access data center. It is possible to reduce power usage under unusual circumstances, such as weather, by using a duty-cycling strategy.

Due to a lack of irrigation resources worldwide developed a precise and efficient water management approach to maximise irrigation availability (Nikos et al., 2019). Dry conditions may make it hard for plants to breathe, which can cause their leaves to become yellow and eventually fall to the ground in clumps. Plant death is the result of this condition, and the rest of the farm will have the same issue soon enough. To determine the degree of plant thirstiness in PAF, one must focus on and watch the yellowing leaves and sprinkling on the ground utilising wireless sensor equipment.

Have proposed WSN technology as a means of aiding farmers in addressing the dual problems of excessive and insufficient watering of agricultural fields (Kanade and Prasad, 2021). For these problems, there is automation technology based on WSNs that aims to improve energy management, efficiency, and latency. The suggested approach is used to optimise irrigation infrastructure throughout the farm, ensuring that all crops are watered by the irrigation system. With the help of GSM cellular technology, the farmer receives updates on agricultural operations in the field of the crop through text messages. To maximise irrigation efficiency in crop management.

Have built a network model for storing agricultural sensor data that makes use of multiple cloud systems using different service providers for redundancy and cost savings (Maniyath et al., 2018). Optimisation methods are put to use when cloud computing is used with the IoT to optimise sensor data in real-time on a global scale.

Have suggested using a deficit drip irrigation technique to make better use of water supplies (Kanade et al., 2021). The sensor's data might be sent to the cloud for further analysis depending on the estimated amount of water needed by each plant species in the field. The data is used to provide recommendations for improving irrigation practices across agricultural sectors, helping farmers provide enough water for all their crops.

Proposes a method of operating wireless sensor nodes that relies on static clustering strategies is described (Rommer et al., 2019); this method ensures that the whole agricultural area is exposed to light in the most effective and precise manner possible. A more effective way to address the coverage-hole issue is to use a mix of node types in different locations, depending on the task at hand and the available resources. The networked sensor nodes are constantly gathering data about the surrounding environment. The sensed data received about the environmental element in the agricultural area is only communicated to the BS if the value of the user-defined Periodic Timer (PT) or detected characteristics exceeds the desired limit.

3 Problem statement

Recent WSN studies have targeted agriculture intending to improve upon established farming practises. The miniaturisation and decreasing cost of MEMS technology has made previously inaccessible sensors practical. Due to their scalability, compact nodes, and inherent benefits of self-organisation, WSNs are a great alternative for automating agricultural procedures. The development of WSN-based applications for smart agriculture has considerable obstacles due to the limitations of WSNs in processing power, memory, and battery life. Using WSN based agricultural solutions shouldn't need consumers to take on more debt. In multi-hop WSNs, energy usage might differ across nodes. The fraction of nodes transferring packets to those near the base station is much greater in regions where the nodes are situated due to the nodes' role as routers. The greater packet throughput requires more power at the node level. Because of its powerlessness, the node can no longer communicate with the rest of the network. When a node is eliminated, all of the other nodes that were relaying for it are also shut off. Because of these energy-saving measures, the WSN application continues to operate under these conditions. Finding the root reasons for growing energy consumption is a prerequisite for developing effective remedies.

3.1 Objectives

- Predicting future crop temperatures, humidity, and soil moisture by analysing sensor data.
- To keep an eye on crop quality, use sensor data (both historical and real-time) to accurately predict the occurrence of pests and diseases.
- An automated smart power irrigation system at a reasonable price is the target.
- Conceive, design, and implement a multi-sensor system to ascertain the field's online and offline status in real time.
- Our goal is to provide a solution that significantly reduces the power consumption of a WSN node.

3.2 Current status of the research

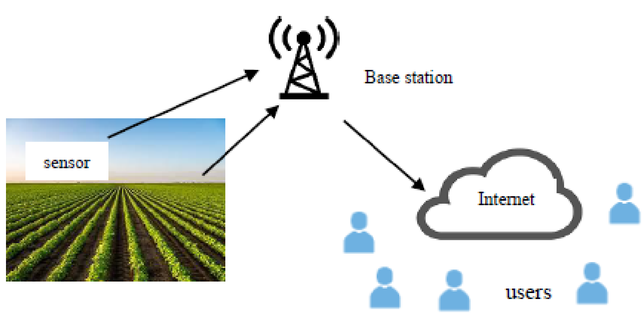
Israel used the IoT to create a highly productive agricultural system in a previously unproductive area. Israeli farmers have achieved precise watering, environmental information collection, and anger control for farming with QR codes, radio frequency technology, network monitors, and various environmental sensor devices thanks to the guidance of users provided by big data during fertilisation, irrigation, after-sales, and other key operations. The farm uses solar panels to harness the continent's abundant solar energy, collects water from nearby rivers, wells, and groundwater, and stores it in tanks for later use in a precise drip irrigation system (Shen, 2021). Sun Culture is widely used in African gardens and orchards to increase output while decreasing input expenses. The business has garnered a lot of attention and support. There are many specialised areas within agriculture, such as agroforestry parks, food and culture, rural landscape decoration, mountain living, and ongoing education. A pilot program to install wireless LAN in agricultural land to map plant development and enable remote greenhouse control to increase production while decreasing labour costs has shown encouraging results, paving the way for innovative farming made possible by the model's use of IoT technology. Potential applications of self-organising WSNs in animal research were uncovered through a study of the impact of the environment on animal body temperature.

Improvements have been made in the cultivation of high-quality crops, the breeding of animals, and the tracking of food products. With the use of computers and wireless technology, Bansal et al. developed a system to manage greenhouse environments from afar. By following these steps, the CO2 and temperature in the greenhouse can be maintained at a steady state. Recreational farming was first proposed by (Nicolescu et al., 2018); it allows users to track the growth of land plants in real time over the internet and provides a forum for farmers to share their knowledge and enthusiasm. Typical industrial IoT applications are tailored to their client's demands, and IoT technology is now finding new uses in leisure agriculture. However, there is no global industry standard and numerous closed-loop IoT devices are designed and manufactured. Multiple in-field sensors are needed to use IoT in hobby farms.

3.2.1 Agriculture prototype

To effectively schedule watering operations, the prototype farm shown in Figure 3 uses real-time, distributed wireless sensor technology to detect and quantify environmental data such as soil moisture and temperature. The device may be used to monitor the weather as it happens, but it can also help with water and energy management, among other ecologically responsible choices. The information stored in local and remote databases is made available through an intuitive mobile app. Customers will be able to keep an eye on or even manage their farms from the palm of their hand using their cell phones. The overall system is intended to be energy-efficient, cost-effective, and low-maintenance to assist farmers and customers maintain their farms or gardens with as little effort as possible. This setup consists of a gateway, six WSNs, and a meteorological control unit.

Figure 3 Prototype farm (see online version for colours)



3.2.2 Nodes of sensors

The wireless sensor nodes' core functionality is provided by Arduino modules, and their communication with other sensors is handled via interface boards. The sensor board reads soil moisture, pH, leaf wetness, ambient temperature, humidity, solar radiation, air pressure, soil temperature, and meteorological parameters like wind direction, precipitation, and wind speed. Using the ZigBee protocol and XBee PRO S2, nodes can transfer sensor data to the gateway at 2.4 GHz. Integrated Development Environment can program sensors (IDE). Each WSN includes a 3.7 V, 1150 mAh lithium-ion battery.

3.2.3 Gateway for IoT

A Linux-powered mesh router that works as a gateway to the IoT stores the gathered sensor data in a MySQL database. While the gateway may communicate with sensor nodes using a wide number of wireless protocols, the ZigBee standard is being used in this implementation. And since it supports both Wi-Fi and Ethernet connections, syncing data between local and remote databases via a cellular or wireless connection is a breeze. The gateway might also transmit sensor data to a cloud-based database. Recent data may be accessed using the gateway's user interface app, as shown in Figure 3.

3.2.4 The cloud and services

The gateway sends collected sensor data to commercial cloud service platforms with limited storage space, such as Microsoft Azure and Google Firebase. The cloud makes it simple and flexible for users to get to their data. This opens the door for future uses including remote access to farm data, data analytics, and agricultural guidance. This 'smart farm' technology collects data that can then be accessed through the web and mobile devices.

3.2.5 Application

Using a mobile application, we will transmit sensor data in real time to the cloud, which will help us achieve our project goals. Users of the mobile application platform may keep tabs on more than just the health of their farm by keeping tabs on things like energy use, irrigation schedules, and weather conditions in real time.

3.2.6 Analysis of data

In this research, we concentrate on using high-resolution sensor data to make accurate predictions about agricultural productivity, weather, and crop quality. By reducing the amount of chance that crops are exposed to in the field, the IoT has the potential to increase agricultural yields and production. Farmers may gain an understanding of energy production, water usage, water recycling, and crop quality via the application of the data-driven physical model. Long-term weather data monitoring may be used to create a time-series prediction model that can accurately forecast the weather a day in advance, allowing farmers to plan irrigation systems. The mobile app's dashboard will alert the user when it's time to irrigate. Sensors' potential for collecting large volumes of data poses problems for data management and storage, but it might lead to the identification of useful predictive patterns in agricultural datasets. The project's data analysis is only getting started; further data processing and mapping are required. Research activities for data analysis are listed below,

1 Acquiring, organising, and analysing information from various systems, such as those dealing with agricultural production, power generation, and water distribution. This is a pivotal phase since the scale of this effort covers several ages and regions.
2 Several types of machine learning simulations are implemented.
   - It may be able to determine what influences agricultural production, FEW interactions, and the quality of your crops by using the Classification and Regression Trees (CART) method.
   - Blending deep neural network-collected WSN data with information gathered from external sensors.
   - Model testing and analysis.
3 Projected values are being added to a mobile and online app that is now undergoing maintenance and updating.

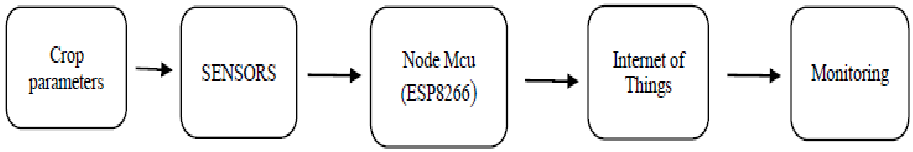
4 Research methodology

The data analysis for this project is only getting started; further data processing and mapping are required. The researchers that pursue the data analysis path are responsible for the following types of work:

- Systematic data collection and analysis of plant, electrical, and water processes.
- The term 'data pre-processing' refers to the steps used to clean, prepare, and make ready raw data for further analysis. This stage is essential because of the temporal and spatial complexity of the project.
- Deep neural networks were trained using remote sensing data and then used to the WSN data to enhance it.
- An app accessible on both smartphones and computers displays predicted outcomes.

The challenge of monitoring large and small regions is highlighted, and a strategy for doing so at ground level is presented. With the use of sensors and an IoT platform, we have developed a system to keep an eye on farmland. Figure 4 depicts the three architectural layers – deployment, service, and application – that contribute to the total processing. For monitoring fields of varying sizes, the suggested system employs three distinct operational levels. The software could collect data on soil and climate conditions, then store it, process it, analyse it, and provide the results to the user. The suggested technique provides rapid access to visual representations of acquired field and meteorological data for farmers. When an event happens, the system will send an alert message to each user by email or text message. Using WSNs and IoT technologies in agriculture aims to provide real-time crop monitoring and the most efficient and effective solutions to issues in the agricultural sector.

Figure 4 Monitoring flow



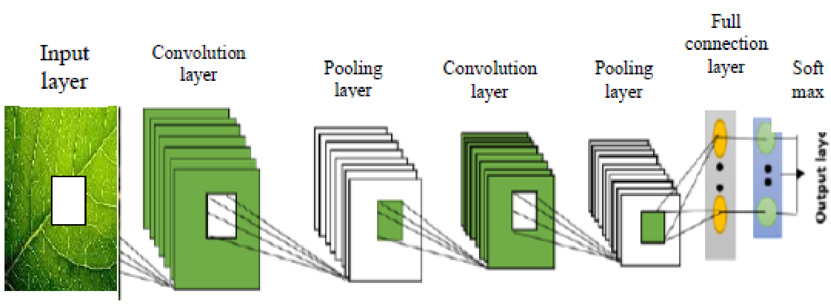
4.1 Sample size

The dataset including 2500 samples is taken and then they are evaluated on various parameters step by step.

4.2 Hardware details and description

Sensors for light, ultrasonic, LCD, voice, Arduino, soil moisture, soil temperature, soil pH, and Raspberry Pi were all employed in this investigation shown in Figure 5.

Figure 5 Details and description (see online version for colours)



Source: Adi et al. (2019)

4.3 Wireless sensors materials

Wireless sensors provide the way for future wirelessly networked applications like the IoT in the cloud, mobile networks, and more. When designing wireless sensors, engineers must take into account a wide range of factors, including the materials' resistance to loss and interference, their conductivity, and their ability to detect and correct errors. Sustainable materials, low-cost materials, recycled goods, materials for the next generation, conductive polymers, Nanotubes, energy-conservation materials, and specialised electronic components are only a few of the categories that have been added to the development model since then. These parts serve a crucial purpose because of the efficient production process and structural modification of their base materials. Electronic tools for building and making devices begin with processing materials like Gallium (Ga) and Arsenic (As). Semi-conductive cubes of Gallium Arsenide (GaAs) and a conductive polymer round out the ingredients.

4.4 *Rainfall sensor*

With the use of the rain gauge, meteorologists can accurately anticipate precipitation levels. The rainfall sensor pad, with its network of exposed copper traces, functions as a variable resistor (for example, it seems to be a potentiometer) whose resistance varies with the height of the water above and below the pad. It has been theorised that lower resistance occurs at higher water levels. The wireless sensor, which consists of a detecting pad with rows of exposed copper traces, is designed to be deployed in an outdoor environment, either over a protective covering or in some other position highly susceptible to damage from rain.

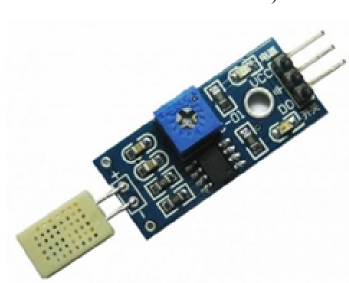
4.5 *Air quality sensor*

Instrumentation for analysing and purifying air after contaminants have been removed. Particulate Matter (PM) in the air may be measured using an alpha sensor. It's possible to connect the sensor to an Arduino board running pollution-sensing software. Any changes in impurity levels may be saved to a USB device and retrieved at a later time. The IoT allows for the remote monitoring of air quality. When particle matter (PM) emissions reach an unsafe level, the filtration system kicks in to clean the air. The air purification chamber should include built-in electronics and mechanical support. After PM is discovered in the air using a quality sensor, it must be removed using the recommended methodological equipment.

4.6 *Soil moisture and humidity sensor*

There, on the soil's surface, are the devices used to monitor the environment's temperature and moisture as shown in Figure 6. To attain the target average air temperature and humidity, it was determined to position the nodes at the level of the crops' margins. The moisture and temperature sensors were placed at intervals of 5 m, with about 5 cm between each pair. When the sensors were ready, they were planted at a shallow depth. Specifically, the FC-28 soil moisture sensor is used in our setup. Input voltages of 3.3 V to 5 V are supported by this sensor. The range of the possible output voltage is 0–4.2 V. The LM393 comparator is vital to the operation of this sensor. The outputs are available in both analogue and digital formats for your convenience. The digital output from the sensor is read by an Arduino Uno. Whether or whether the ground is damp affects the value produced.

Figure 6 Humidity sensor (see online version for colours)



4.7 Temperature sensor

It was determined by the use of an LM 35 temperature sensor. The linear scaling factor of this sensor is +10 mV/°C. This instrument gives an accurate measurement to within 0.5 degrees. This sensor may be relied upon when used in non-invasive situations. In a temperature range from –55 to 150 degrees, the gadget continues to function normally.

4.8 Soil pH sensor

The pH of the soil is an indication of its nutrient quality. Our work with soil necessitates the use of a Labman pH meter to measure the acidity of the ground. In general, soil pH ranges from 1 to 14. Soil pH values between 6 and 7 are acidic, 7 and 8 are neutral, and 8 and above are basic. The Labman pH meter has an operating temperature of between 0 and 100 degrees Celsius. The pH scale is accurate to within 0.01 pH.

4.9 Light sensor

The LM393 light-sensing microcontroller was used extensively throughout our investigations. As a sensor, this light-sensitive resistor LDR is used. It requires a power supply between 3.3 V and 5 V to function. One may use a potentiometer to modify the intensity of the light's on/off switch. A digital signal is produced based on this threshold value.

4.10 Ultrasonic sensor

An ultrasonic sensor with the model number HC-SR04 was used in this study. This device requires a minimum input voltage of 5 V. The accuracy is within 3 mm. It operates at a frequency of about 40 Hz. It may be used to measure anything from 2 cm to 450 cm.

4.11 Liquid crystal display (LCD)

In this experiment, we utilise an Arduino with a Liquid Crystal Display (ALCD) to display both input and output parameters.

4.12 Arduino UNO

The microcontroller used here is an Arduino UNO. There are four digital I/O pins available for use. There are six analogue inputs in all. There is no need for more than 5 V for the device to work. With 32 kilobytes of flash memory and 16 megahertz of processing power, it's a very capable device.

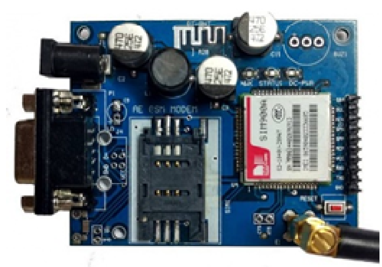
4.13 Raspberry Pi

It includes a Raspberry Pi 3 model B in our system. It can store one gigabyte of data in the available RAM. Constructed using the same protocol as Ethernet 100 Base. This portable gadget is both inexpensive and practical. One may insert a microSD card to increase the device's storage capacity. Adding it to our system is a breeze.

4.14 IoT module

IoT sensor nodes are battery-operated, portable, and wireless as shown in Figure 7. Multiple such small sensors would typically be used in an IoT application system to continually monitor the weather over a large area. The paper provides an energy-efficient idea for IoT-enabled PA that is based on the architecture of solar power systems. Using environmental data, solar power models attempt to foretell future solar power output.

Figure 7 IoT module (see online version for colours)



4.15 Relay network

Relay nodes are required to ensure and implement fault tolerance in WSNs. Router-based sensor cluster header fusion and outbound transmission to target/sink in a remote wireless sensing device Due to low-power, resource-intensive routing approaches, nodes contemplate multi-hop wireless routes involving numerous nodes.

4.16 Data preparation cum generation

Our experimental investigation used a dataset taken from the publicly available Kaggle database. Seven characteristics, including pH, rainfall, temperature, humidity, nitrogen, potassium, and phosphorus, are provided in the lookup format for the crop-recommended dataset. All sorts of crops may be made by combining these seven traits in different ways. The proposed crops and numerical values for each of the seven parameters are presented in a lookup list.

5 Hardware implementation

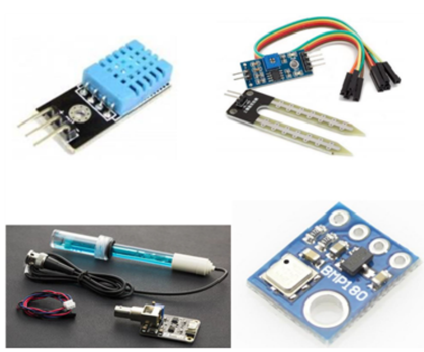
These schemes aim to better organise agricultural land and expand the reach of a centralised monitoring system. This can be controlled remotely from just about anywhere with a mobile phone and some wireless capability. Irrigation, environmental, soil moisture, and fertiliser data collection are all operations that may be managed by software users without the need for a person to be present. Each farm that uses the app may benefit from an in-depth analysis of crop performance, tailored harvest recommendations, and accurate crop forecasts. The environmental elements that the sensor network is designed to detect include temperature, soil moisture, humidity, and light. This model is used to determine which farming practices will be used on each piece of land. A collection of these nodes' data is then uploaded to the cloud. The data obtained is kept in a database hosted in the cloud. Sending information to a cloud database makes sense for long-term storage. Farmers may log in to their accounts to examine their nodes' complete historical data as well as the most up-to-date readings.

5.1 Automated, intelligent irrigation system for high-precision farming

SIS-PAF is recommended for precision agriculture to eliminate the shortcomings of current implementation techniques. This technology reduces irrigation water waste to combat the worldwide water crisis. The proposed method uses cloud computing data gathered on the website to organise and control to keep farmers updated on its status. The system incorporates Arduino Uno, a moisture sensor, and a GSM modem for wireless communication. We use a GSM modem and a Hypertext Preprocessor-created website to get Arduino data to farmers in remote areas. The website is built online and maintains a database of data collected from a variety of wireless sensors that are given data through hardware peripherals. An irrigation system's threshold value is adjusted to regulate sprinklers for diverse crops. By adopting this system, just the necessary amount of irrigation water has to be given. To increase agricultural yield productivity via more efficient use of agriculture resources, the use of IoT-based agriculture platforms is a game-changer for the agriculture sector as it now stands. More benefits may be gained by large-scale farmers by remotely monitoring and manipulating numerous aspects. IoT-based technologies may be made more accessible to farmers with the aid of a system administrator.

The DHT11 Arduino sensor, shown in Figure 8(a), is capable of monitoring both temperature and humidity. Agricultural soil moisture may be measured using a hygrometer sensor, as shown in Figure 8(b). The PH meter's probe is seen in Figure 8(c). The hydrogen ion acidity of a water solution may be estimated using the pH meter's sensor. A device for measuring atmospheric pressure in an agricultural setting is seen in Figure 8(d).

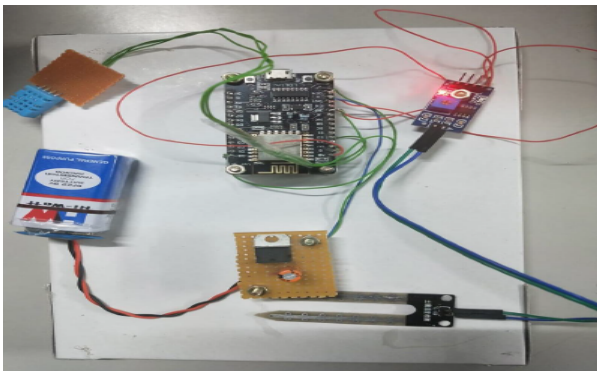
Figure 8 (a) Four-pin DHT11 for Arduino; (b) hygrometer sensor; (c) PH meter sensor and (d) air pressure sensor (see online version for colours)



5.2 Wireless sensor's transmitter

It can monitor environmental factors like humidity and temperature by keeping the wireless sensor's transmitter out in the field as shown in Figure 9. All of the settings and configurations are stored in one convenient location. The irrigation pumps are kept in different parts of the agricultural field so that water can be delivered to a crop area as needed after researchers examine the various information of various measures that have been preserved in the central server at various times since the agricultural field status.

Figure 9 Wireless sensor's transmitter (see online version for colours)



6 Result and discussion

After the necessary hardware and software have been established, tests must be carried out to determine whether or not the proposed remote control device satisfies the requirement of collecting field data. The coordinating part receives the first data from the wireless sensor in the experimental portion through the simplest wireless network. The coordinator then disseminates the data across the wireless communication network using the wireless information packet network module. The third phase involves sending the data to the user's gadget. A variety of tasks are completed and information is shared here. Wireless sensors have become more common in agricultural settings, although just three typical sensors were used for this study. Taking humidity and temperature measurements of farms Since temperatures will likely fluctuate as the experiment progresses, keeping tabs on a broad upward or downward trend is unnecessary. There is a temperature and humidity sensor that reports the current climatic conditions in real time. Maintaining a maximum daily temperature and humidity level conducive to agricultural growth is all that has to be done. It also shows that the ideal temperature and humidity for farming are opposites. Figure 7 shows that, despite the anomalous data values recorded by some sensor nodes at a particular time, the rule of change in temperature and humidity data received by sensor nodes is generally the same.

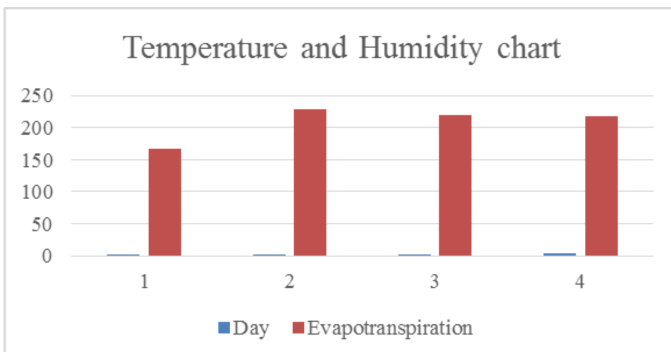
6.1 Project result description

Here, we present the results of an experiment in which home plants were used to determine how precise a moisture meter might be. After analysing weather patterns and field data, the best watering schedule is created. One may either manually or automatically manage a motor pump. If it rains on or around the scheduled irrigation day, watering may be postponed for a few days until the system has recovered from the deluge. The capability of soils to hold water is also investigated in this research. This intelligent technology evaluates the soil moisture forecast figure for four consecutive days to make sure it is accurate. In a few days, the encrypted soil moisture data will be accurate and reliable enough for this purpose. In cases when the MSE is low, kernel-based support vector regression (SVR) is used.

6.2 Temperature and humidity

Figure 10 represents the temperature and humidity chart. The evapotranspiration is recorded for four different days and it is noticed that its value increases with an increase in the number of days.

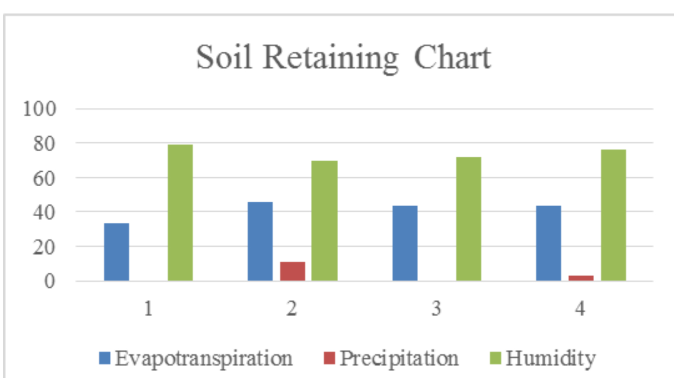
Figure 10 Temperature and humidity chart (see online version for colours)



6.3 Soil retaining capacity

The soil retaining chart is presented in Figure 11 to record the values for Evapotranspiration, precipitation, and Humidity for different days. The variation in their values is shown.

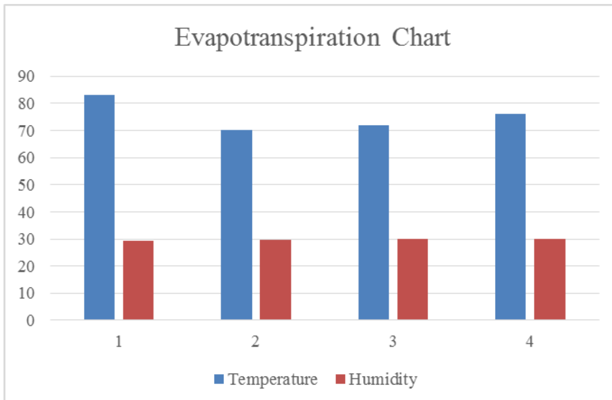
Figure 11 Soil retaining chart (see online version for colours)



6.4 Evapotranspiration

The Evapotranspiration Chart is indicated in Figure 12 for recorded values of temperature and humidity. The variation in their values is shown (Table 1).

Figure 12 Evapotranspiration chart (see online version for colours)



6.5 Prediction model

The days and moisture content for irrigation are shown in Table 1. It lists a few potential considerations for choosing when to irrigate. Some farmers plan irrigation to start after a certain number of days. This does not consider times of high stress, like a string of days with a high temperature and/or evapotranspiration. Others make use of soil moisture probes. When it rained, and the average daily evapotranspiration was lower, more time was permitted between irrigations. Local characteristics specific to each sensor may account for some differences between them. Such elements consist of root development and soil cracking. To minimise these sources of unpredictability, several sensors are required. This variance is probably caused by the sequence in which the plots are irrigated (with later-irrigated plots experiencing greater water stress) and variations in topsoil depth after laser levelling.

Table 1 Moisture content and irrigation requirement

Day	*Moisture content*	*Irrigation requirement*
1	56	1
2	36	1
3	29	1
4	36	1

7 Simulation performance analysis

The technology is tested in a simulated environment to determine its efficacy.

7.1 Simulation analysis

The proposed framework's performance is evaluated in two ways:

i separately for the WSN and WiLD networks

ii overall, depending on the results of the first stage.

We used a Skymote gadget based on the CC2420 platform in the Contiki Cooja simulator to mimic 6LoWPAN. To ensure a large number of hops, 50 nodes are placed in a network with a fixed distance from the sink.

Figure 13 Time-consuming comparison of the item-by-item operations (see online version for colours)

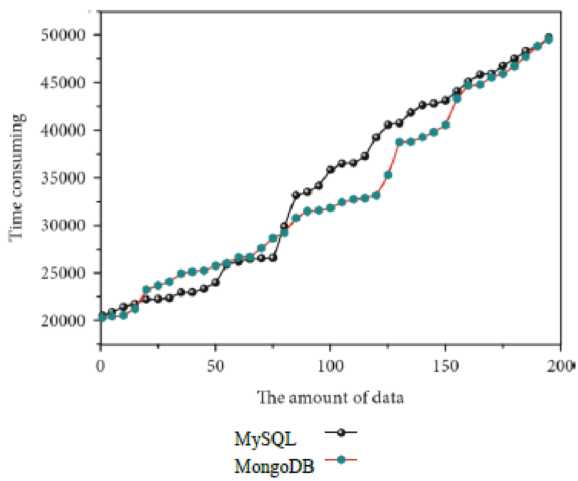
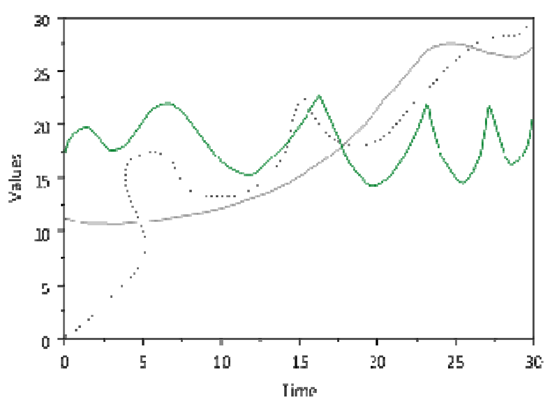


Figure 14 Data statistics analysis interface (Temperature, humidity, PPM) (see online version for colours)



Increasing the network's node count results in a decrease in throughput (Figure 13). This is due to numerous packet losses brought on by intense channel congestion and frequent channel checks. The recommended technique outperforms the alternatives. When nodes in the middle of the hierarchy attempt to become accessible, it shortens the amount of time the queue is at rest. Since it prioritises downstream traffic to reduce latency, the suggested protocol outperforms competing methods. The energy module in Contiki is what is used to determine how much power each node needs every second. When comparing the constant duty cycle MAC technique to the LPL length, there is a substantial difference in power usage. The WSN-IoT example demonstrates a common flowchart for machine learning, machine testing, and WSN action processes (Figure 14).

8 Conclusions and future work

Similar to other industries, agriculture is digitalising. Farmers have provided more and better data. In recent years, interest in IoT, robots, drones, WSNs, and AI has risen. Machine learning algorithms can sift through big data to find helpful information. Researchers use machine learning models in precision agriculture to estimate productivity and identify weeds and diseases. Using ML to analyse sensor data, farm management systems are becoming AI systems that give decision-makers trustworthy insights. Concerns about implementing an app and the infrastructure needed to handle its data are addressed, as are crop quality, output, and weather forecasting challenges. Distributed (or edge) deep learning may become more popular in the next years. AI could boost farm output, farm labour efficiency, and natural resource conservation. We studied the usage of IoT technologies and WSNs in agriculture and proposed a strategy and set of concepts to achieve this goal. The screenshot operation module's screenshot data are blended with video synthesis to create a video. Recording operation module and camera access module record audio and video based on database information.

This technique combines recreational farming with modern computer technology to offer real-time online farm administration through the web. It's also a platform for developing a cutting-edge approach to agricultural enterprise. The system's key components were designed using object-oriented concepts, and the abstract factory pattern was introduced in the user self-customisation module before being reviewed and improved upon to make the system more flexible and scalable.

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