International Journal of Engineering Research & Management Technology
(Peer-Reviewed, Open Access, Fully Refereed International Journal) ISSN: 2348-4039
Volume 11, Issue-6 November-December- 2024 Impact Factor: 7.09
Email: editor@ijermt.org www.ijermt.org

ASSESSING THE IMPACT OF IOT-BASED SMART FARMING ON CROP YIELD AND RESOURCE MANAGEMENT IN INDIAN AGRICULTURE

Sushil Kumar
Research scholar, Department of computer science & Applications
M.G. Kashi Vidyapith, Varanasi.

Prof.Dr. Satya Singh
Department of computer science & Applications
M.G. Kashi Vidyapith, Varanasi.

Abstract:

The introduction of the Internet of Things (IoT) has resulted in revolutionary developments across a variety of industries, including agriculture. Agricultural production continues to be an important economic activity in India; thus, the implementation of Internet of Things (IoT)-based smart farming technologies has the potential to considerably improve crop productivity as well as resource management. The purpose of this study is to investigate the influence that Internet of Things (IoT)-based technologies, such as sensors, data analytics, and automation systems, have on the effectiveness and sustainability of farming operations in India. The Internet of Things helps farmers to make educated decisions that optimise resource utilisation, decrease wastage, and enhance overall crop output. These decisions are made possible by the integration of real-time data collecting on soil moisture, temperature, crop health, and water consumption. Additionally, the economic and environmental benefits of the Internet of Things (IoT) adoption are investigated in this research. These benefits include the saving of water, the reduction of fertiliser consumption, and the enhancement of agricultural resistance to climate change. In addition to this, it examines the obstacles that must be overcome in order to achieve widespread acceptance of these technologies, such as limits in infrastructure, impediments to digital literacy, and costly financial obstacles. According to the results, Internet of Things (IoT)-based smart farming has the potential to revolutionise Indian agriculture. However, in order to overcome these problems, there must be a combined effort from the government, the corporate sector, and farmers. The purpose of this study is to emphasise the necessity of regulatory frameworks, training programs, and investments in rural digital infrastructure in order to encourage the adoption of smart agricultural methods across the nation.

keywords: *IoT-Based, Smart Farming, Crop, Agriculture*

Introduction:

Agriculture serves as the foundation of the Indian economy, creating jobs for more than half of the country's population and making a sizeable contribution to the gross domestic product of the country. Nevertheless, despite its significance, the industry is confronted with a number of issues, such as a decrease in output, poor utilisation of resources, unpredictable weather patterns, and restricted access to contemporary technologies. In order to solve these difficulties, the implementation of cutting-edge technology such as the Internet of Things (IoT) in agricultural operations provides a potentially fruitful answer. Smart farming systems that are based on the Internet of Things collect real-time data from fields through the use of sensors, data analytics, and automated controls. This gives farmers the ability to make decisions based on the data, which helps them optimise crop production and resource management activities. An increase in crop output, a reduction in the excessive use of resources such as water and fertilisers, and the promotion of sustainable agricultural methods are all potential outcomes of the implementation of the Internet of Things in India, where the bulk of farming is still done in a conventional manner. For instance, Internet of Things (IoT)-enabled soil moisture sensors and climate monitoring systems can assist farmers in determining the exact quantity of water that is required, therefore enhancing the efficiency with which they utilise water. The Internet of Things (IoT) may also be used to power pest monitoring systems, which can minimise the need for chemical pesticides, so reducing both costs and the impact on the environment. It is possible for the Internet of Things to contribute to more informed decision-making and improved resource management by giving farmers with real-time information regarding the health of the soil, the conditions of the crop, and environmental elements. However, despite the tremendous promise, the implementation of Internet of Things (IoT)-based smart farming in India is still in its early phases. This is due to a number of obstacles, including poor infrastructure, high initial expenses, and a lack of digital literacy among farmers. On the other hand, there is a tremendous potential to bridge these gaps and extend the advantages of the Internet of Things to a wider range of Indian farmers as a result of the rising push for digital agriculture from both the government and the corporate sector. In India, the purpose of this article is to evaluate the influence that Internet of Things (IoT)-based smart farming technologies have on agricultural output and resource management. In order to provide policymakers, farmers, and industry stakeholders with insights on how to utilise new technologies to boost agricultural production and sustainability, it will conduct an analysis of the advantages, difficulties, and future possibilities of integrating the Internet of Things (IoT) into Indian agriculture.

Research Objectives

1. To Analyse the impact that technologies based on the Internet of Things have on increasing crop yields.
2. To Analysis of the Internet of Things' influence on resource management
3. To investigate the economic and environmental advantages of farming based on the internet of things.

Methodology

The materials and procedures that were utilised in the process of creating and implementing the Internet of Things smart farming system are gone over in great detail in this part. This covers the creation of prototypes, as well as the hardware and software components, as well as the architecture of the system.

System Design

Figure 1 depicts the block diagram of the intelligent agricultural system that has been presented. In it, the hardware components that were utilised to construct the prototype are depicted, along with the ways in which those components interact with one another to produce the smart farming technique.

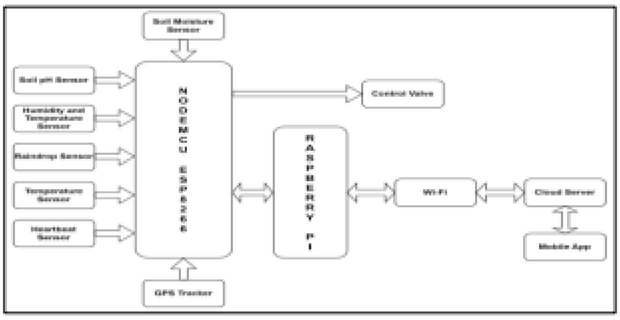

Fig. 1. Block diagram of smart farming system

NodeMCU ESP8266: A type of microcontroller known as the NodeMCU comes equipped with an ESP8266 Wi-Fi module that is integrated right in. Lua script or the C/C++ programming language may be used to write code for it, and the Arduino IDE can be used to do it. Before connecting to the Raspberry Pi, this microcontroller is suited for handling the Wi-Fi connection that is between the Internet of Things sensors and devices to the Raspberry Pi.

Raspberry Pi: It is possible to connect an external monitor, keyboard, and mouse to the Raspberry Pi, which is a low-cost and compact computer that can be hooked into external devices. Python, C++, and Java are examples of programming languages that are typically utilised in the process of programming it. Due to the fact that it is capable of managing more complicated programs, one of its applications is to create a connection to the NodeMCU, which then allows signals to be sent to the control valves in order to carry out the orders that are given by the user or application.

IoT devices: When it comes to the crop monitoring system, the Internet of Things devices that are utilised include a soil moisture sensor, a soil pH sensor, a humidity sensor, and a temperature sensor. In the case of livestock monitoring, the temperature sensor, the heartbeat sensor, and the GPS tracker are utilised. Another important function of the control valve is to regulate the flow of water and fertilisers during the irrigation process. This is accomplished by controlling the flow of water.

Arduino IDE: Arduino's integrated development environment (IDE) is a software platform that enables Arduino devices to be programmed. However, despite the fact that it is most often utilised for programming Arduino boards, it is also designed to be compatible with other types of microcontrollers. Its primary function in this project is to be utilised for the purpose of programming the NodeMCU ESP8266 microcontroller. Lua script and C/C++ languages are among the programming languages that are supported by the Arduino integrated development environment (IDE).

ThingSpeak: A cloud-based data visualisation and analysis of live data are two of the services that are included in the Internet of Things analytics platform service known as ThingSpeak. The ThingSpeak API is responsible for collecting incoming data, assigning a timestamp to it, and providing the output to both humans and machines. Users are able to construct apps for data gathering, data processing, and simple data visualisations by utilising the data obtained from the sensors to create these applications with the help of ThingSpeak.

Android Module/App: For the purpose of serving as a centralised dashboard, the smart farming system that has been suggested includes a mobile application that the farmers may use. The module is put on the farmer's smartphone in the form of an Android application, and they may use it to access the precision irrigation function, as well as monitor the state of their crops and livestock by connecting to the Thing Speak Cloud. The equations

Communication architecture

In this part, the communication architecture will be explored in order to describe how the hardware components and software may be connected together in order to function as a single intelligent farming system. This discussion will be based on the hardware and software that have been mentioned. Initially and most importantly, the NodeMCU ESP8266 microcontroller establishes a connection with the sensors in order to gather information on the agricultural field and livestock. Because it is impossible to utilise cables for connecting in a vast area like a farm, the ESP8266 Wi-Fi module makes it possible for the microcontroller to connect to the sensors over a Wi-Fi connection. This eliminates the need for intricate cabling. In order to configure the Wi-Fi connectivity, initialise the sensors, and manage the data collection and transmission, you will need to write some fundamental code using the Arduino Integrated Development Environment (IDE). Once the code has been created, it may be uploaded to the NodeMCU, which will then subsequently be used to establish the connection between the sensors and the NodeMCU. The NodeMCU microcontroller is now linked to the Raspberry Pi, which brings us to the next step. Data analytics programs, such as disease detection for crops and animals, may be built using the Thonny integrated development environment (IDE) and then uploaded onto the Raspberry Pi. This is possible since the Raspberry Pi is capable of handling more complicated programs that are written in Python scripts. Additionally, the Raspberry Pi serves as the medium that is responsible for receiving the sensor data from the NodeMCU and then transmitting orders to the motors that are attached to the water valves or feeders in order to begin the essential operations. Following this, the MQTT (Message Query Telemetry Transport) protocol is selected as the primary communication protocol to link the devices to the cloud server. This is done in order to ensure that all of this data is transmitted to a cloud server, which in this instance is the ThingSpeak Cloud. This is due to the fact that the smart farming system need regular data updates from the sensors. The publish/subscribe paradigm of MQTT makes it possible for more efficient data transmission since it eliminates the requirement for continuous polling. In addition, MQTT is a lightweight protocol, which makes it more suited for the implementation of the smart farming system. This is essential since the majority of farms are situated in regions with restricted bandwidth. Furthermore, the scalability of MQTT makes it possible to have effective communication among systems that are made up of a huge number of interconnected devices. The next step is to use ThingSpeak to generate straightforward visualisations of the sensor data. These visualisations can then be uploaded to the Android app on the farmer's smartphone, allowing the farmer to view the real-time data of the agricultural field and cattle. It is also possible to access the programmed features, such as precision irrigation and smart feeding, using the Android app. These functions may be used to send commands to the Raspberry Pi, which will then execute the commands by sending signals to the motors that are attached to the various end devices.

Mobile applications prototype

Within this part, the prototype of the mobile application for smart farming is presented in the figures that follow, along with explanations of the mobile application. The smartphone application functions as a centralised dashboard that allows farmers to monitor the conditions on their farm all at once, and it is designed to be accessible to them at their fingertips. Figure 2 illustrates the crop monitoring interface, which provides the entirety of the information on the agricultural field.

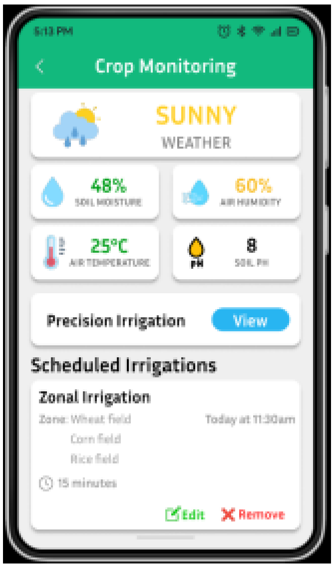

Fig. 2. Crop monitoring interface

On top of the interface, data such as the soil moisture level, pH level, weather, air humidity, and air temperature are presented. This information is based on Figure 2, which represents the interface. The irrigation schedules that were previously established for various parts of the farm are displayed at the bottom of the website. If the farmer want to examine further information on each agricultural field, they can do so by pressing the "View" button on the Precision Irrigation system, which will take them to the subsequent page with the information seen in Figure 3.

Fig. 3. Precision irrigation interface

Through the use of this website, the farmer is able to monitor the state of each individual agricultural field. In addition to this, it reveals the deficiencies in nutrients that the crop field is lacking and suggests a fertiliser that the farmer should use in order to compensate for the deficiencies in a particular nutrient as well. Additionally, farmers have the option to choose whether or not to activate the automatic watering settings. Last but not least, the interface for monitoring cattle is depicted in Figure 4. A heatmap of the livestock's movement and the current state of their health is displayed. Following the completion of the weighting process, the farmer is able to manually enter the mass of the cattle into the body mass line graph.

Fig. 4. Livestock monitoring interface

Circuit prototype

In the next part, the prototype of the component circuit that is responsible for certain functionality that is engaged in the system will be explored and explained in detail, along with an example circuit that will be provided.

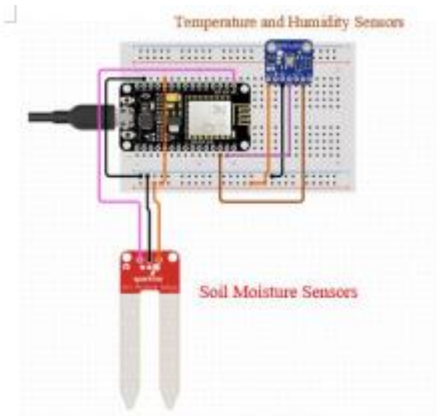

Fig. 5. It is a sensing component for the temperature and humidity of the moisture.

A wire cable will be used to provide power to the NodeMCU, which will be linked to the sensors in the manner seen in Figure 5. Once the environmental factors are captured by the sensors, they will be converted to an electrical signal and transmitted to the NodeMCU through the wire, and from the NodeMCU, the signal will be converted to a data package based on the configuration and transmitted to the Raspberry Pi, which is the centralised data processing unit. In order to guarantee the convenience and dependability of the sensing component, it will be necessary for the component to be supplied by a mobile power supply, such as batteries. Consequently, the team has conducted a certain amount of study, and in the end, a solution will be referred to in Figure 6.

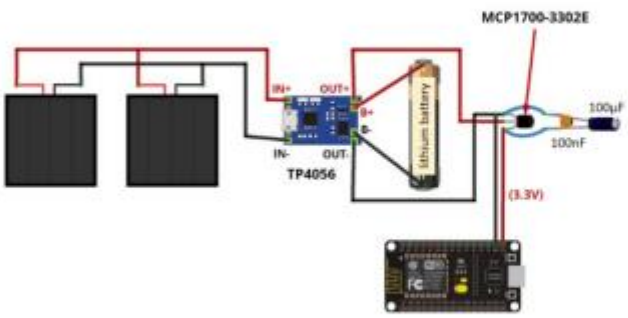

Fig. 6. Power supply using solar panel and lithium battery

In order to avoid the overvoltage of rechargeable lithium batteries and to reverse the polarity connection, the solar panels were linked to a component called TP4056, which is a charging module for circuit protection. This is shown in the picture. While this was going on, the power regulator component, MCP1700, was put into place, and then the ceramic capacitor and the electrolytic capacitor were added. This was done in order to smooth out the voltage peak to ensure that the NodeMCU in our sensing component could function properly.

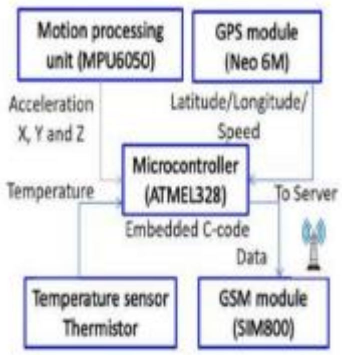

Fig.7. livestock monitoring block diagram

According to the findings shown in Figure 7, the ATMEL328 was used as the microcontroller for this component during the investigation. Through the use of the GSM module, which is represented by the SIM800 in the picture, the data will be sent to the server. The design, on the other hand, is not suitable for our project; hence, the ATMEL328 component and the GSM module will be replaced by the NodeMCU, which is more compact and less expensive. In order to lessen the difficulties of the implementation, the signal that is generated by the sensors and the GPS module will be converted into a data package and then sent to the centralised data processing unit over the network connection.

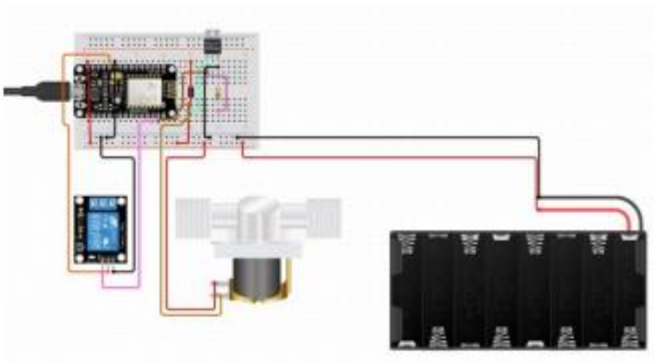

Fig. 8 Solenoid Valve for precision irrigation

In order to accomplish the goal of precision watering, a straightforward circuit that was linked to NodeMCU was constructed for the scenario shown in Figure 8. Batteries were used to power the circuit depicted in the figure; however, the power supply and lithium shown in Figure 6 may also be used by the farmers as a power supply for this circuit. In this particular circuit, a relay module had been incorporated into the circuit in order to regulate the circuit from on to off in order to prevent improper access to water or fertiliser supplies.

Architecture Diagram

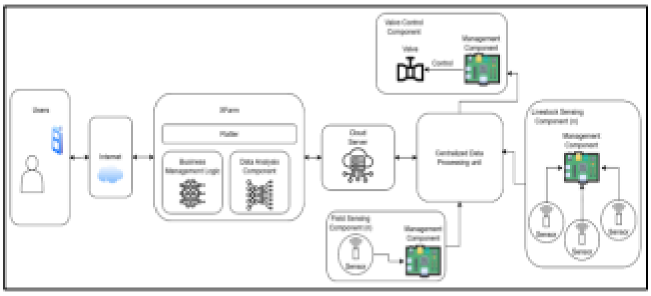

Fig. 9 Architecture Diagram

The architectural diagram that was built for the system, which includes the physical component, is displayed in the figure that is located above. This diagram is intended to highlight how the sensing components are connected to each other. It is only possible for users to access our application through their mobile devices, such as smartphones or tablets, while they are utilising this system. In order to maximise our market competence power, our application will be compatible with both IOs and Android platforms. In addition, the Internet of Things devices that are a part of the system will have a straightforward structure, which will make it less difficult for the components to connect to one another. Additionally, the system will be able to connect with other Internet of Things devices that were not developed by the company. The mobile system will be constructed with the help of Flatter, which is a platform for the creation of mobile applications for open-source software. Because all of the documentation that is associated with the application will be open-sourced and free to access, the team will be able to create the application without having to worry about any cost concerns during the development process if they use Flatter. While this is going on, the software will incorporate the Python programming language for the purposes of data visualisation and data analytics. This system's database will be integrated with cloud-based solutions in order to eliminate any additional financial expenses that may be incurred for the deployment and maintenance of the device. On the other hand, the scalability and flexibility of our system could be guaranteed to accommodate any development of the business or the addition of new users. In addition to the sensing component being developed in the manner described above, the components will be connected to one another through the use of a WiFi connection. The data will be collected by the sensors that are contained within the sensing components, and it will subsequently be sent in a data package to the Raspberry Pi, which serves as the centralised data processing unit. It is necessary for the Raspberry Pi to store the data to the server that is located in the cloud. Because of this, the system was able to visualise the data and display it to the consumers through the respective mobile applications.

Discussion

Artificial intelligence, Internet of Things gadgets, and smart systems are becoming more commonplace among individuals as the industry revolution has begun. Google's replies to the phrase "Internet of Things" or "IoT" have been progressively growing from the year 2010, according to new trends. In addition, ever since 2015, the number of phrases that are associated with this topic has been growing, such as "Smart Farming" and "Precision Irrigation." Based on the findings of the research conducted by A. Khanna and S. Kaur13, it appears that the general public has begun to pay attention to the adoption of Internet of Things (IoT) smart technologies across agricultural operations. On the other hand, the application of machine learning has also been shown to have a beneficial effect on agricultural activities by means of Internet of Things devices and intelligent systems. The application of K Nearest Neighbour (KNN), for example, had resulted in the achievement of completely automated irrigation. According to the findings of the study, the algorithm will make a final decision about the irrigation after doing an exhaustive analysis of the data regarding temperature and moisture that was gathered by the sensors that were installed in the field. An experiment had been carried out, and the results showed that it had a highly favourable effect on the agricultural production in the area where the experiment was carried out. In the meanwhile, the research suggests that the addition of Internet of Things sensors to a decision-making system might be of assistance in predicting and detecting diseases that affect potato plants. This research, on the other hand, has the potential to be implemented in big agricultural farms, despite the fact that the studies are being conducted in an experimental field. Through the research that was conducted, it has been demonstrated without a reasonable doubt that the incorporation of the Internet of Things (IoT) smart technology into agricultural operations would bring about a variety of beneficial effects on farm productivity. If the farmers were to increase the production of their farms, they would be able to increase their revenue by selling the things that they produce. According to the findings of the study that was carried out by Y. Akkem and colleagues16, the use of artificial intelligence algorithms such as ARIMA, recurrent neural network (RNN), and KNN might be of assistance in forecasting the yield of the farm by making use of the time-series data that has been gathered. Predictions might also be made by the algorithm about the categorisation of soil fertility and crop selection in the meanwhile. The application of the intelligent system to agricultural operations has the potential to be of assistance in this industrial revolution, according to all of the scenario studies. When compared to the studies that were conducted, the goods or technologies that were developed had only concentrated on either irrigation or livestock monitoring. On the other hand, the technology that was discussed in this study was able to satisfy all of these requirements at a cheaper cost owing to the distinctive architectural style. The users or farmers will not require any technical expertise in order to execute the system, which generates product distinction from other goods. This is because the system is simple, and the simplicity of the system. Given these circumstances, the system will possess a higher level of competence power than the others, which will ultimately result in a more favourable preference for the users. The restricted technological level and limited compute capacity that the data processing unit possesses will be the one and only constraint of the product For the purpose of lowering the costs associated with the implementation, the components that are chosen will need to be able to attain maximum processing power while incurring minimal expenditures. On the other hand, in order to guarantee the precision of the analysis provided by the system, it will be necessary to install a large number of sensing components and centralised processing units in the field. This may result in significant financial burdens for farmers who have greater amounts of land under cultivation. This will result in an increase in the difficulty of implementation as well as problems regarding component maintenance owing to the increasing number of sensing components that are installed.

Conclusion:

The incorporation of Internet of Things (IoT) technology into Indian agriculture has the potential to bring about a revolutionary change in the way agricultural activities are carried out, particularly with regard to the enhancement of crop output and the optimisation of resource management. IoT has the potential to provide farmers significant insights that will help them to make decisions that are more informed and data-driven. These insights may be obtained through the gathering of data in real time, sophisticated analytics, and automated systems. As a consequence, there is an increase in production, an improvement in resource utilisation, a decrease in expenses, and environmentally responsible agricultural methods. According to the findings of this study, Internet of Things (IoT)-based smart farming has the potential to make a substantial contribution to the enhancement of agricultural yields, particularly in regions where water shortages and poor resource utilisation have been ongoing problems. Through the provision of precise control over irrigation, pest management, and soil health, Internet of Things technologies assist in reducing the excessive use of water, fertilisers, and pesticides, which eventually results in a reduction in the environmental effect of farming operations. In addition, the possibility of mitigating the effects of climate change through the use of climate monitoring systems provides farmers with a useful instrument that can be utilised for the purpose of adjusting to changing circumstances and improving crop resilience. However, despite the fact that the benefits are enormous, the broad adoption of the Internet of Things in Indian agriculture confronts a number of hurdles. These challenges include high initial costs, poor digital infrastructure, and limited digital literacy among farmers. These obstacles need to be overcome by implementing specific legislation, receiving backing from the government, forming public-private partnerships, and implementing education programs for farmers. It is essential to make investments in rural digital infrastructure and cheap Internet of Things solutions in order to guarantee that Internet of Things technology can communicate with the greater agricultural community. This is especially true for smallholder farmers, who stand to benefit the most from such breakthroughs. In order to create an environment that is conducive to the adoption of the Internet of Things, policymakers play a critical role. In order to ensure the success of smart farming efforts, it is necessary to take a number of crucial actions, including providing financial aid to farmers, offering financial incentives for the use of technology, and implementing training programs to increase digital literacy. Furthermore, in order to scale Internet of Things solutions throughout India's diverse agricultural environment, ongoing coordination between the government, the corporate sector, and agricultural stakeholders would be essential.

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