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A literature survey on application of IoT in agriculture

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Abstract: In agriculture, technology use is at previously unheard-of levels. There are numerous innovative agricultural technologies that appear to hold great promise for the industry's future. IoT was previously a cutting-edge agricultural technology, but thanks to increased use, it has moved into the mainstream. The simplest definition of IoT in agriculture is just the Internet regulating things. IoT smart agricultural solutions are made to assist in crop field monitoring using sensors and irrigation system automation. As a result, farmers quickly and hassle-free monitor field conditions from anywhere. In this regard, this paper serves as a review of the literature on IoT-based agriculture. This paper's goal is to provide a summary of internet of things and its various services in farming through discussion of subjects such commercial IoT applications for agriculture, IoT-based agricultural devices, and the advantages offered by these technologies.

Keywords: Sensors, MQTT, Smart Agriculture, NodeMCU

Paper Structure: This review article is organized in few sections. Section I presents Introduction of IoT in agriculture. In Section II Literature review in IoT-based agriculture Section III contains comparison analysis section IV contains roles if IoT in agriculture and Section V contains conclusion.

1. **Introduction:** The extensive use of the cyberspace over the past few years has took countless advantages to businesses and people everywhere. The Internet of Things (IoT) has recently developed improvements that can offer a comparable benefit by improving the human awareness and capability by changing the working atmosphere. IoT proposed a numerous of solutions in different industries, including agriculture, retail, healthcare, smart homes, and security, among others [1]. According to a new United Nations assessment that will be released in January 2023, the present population in the world of approx. 7.7 billion individuals is predicted to increase to approx. 8.8 billion in 2030, approx. 9.7 billion people in 2050, and approx. 11.3 billion in 2100, creating a significant need for food in the following year.

   Food security is a top problem for most nations due to declining natural resources, arable land, and unpredictable weather conditions. In order to meet the food demand in the upcoming years for the whole world, the globe is taking the help of IoT devices and data analytics that can paired with each other [2]. This paper surveys IoT technology in agriculture and includes a review of the relevant literature. This review paper's main goal is to compile all the research publications on the use of IoT in agriculture, including irrigation techniques, MQTT-compatible communication protocols, and field assessments of soil, temperature, and moisture.

2. **Literature Review:**

Different IoT-based innovations for the agriculture sector have been presented by researchers, enhancing production while requiring less labour from workers. The advancement of technology helped in the integration of Internet of Technology in farming area to improve irrigation methods with an aim to save farmer's time. The authors of [3] refers an existing framework to propose a system for optimally watering the agricultural yields using sensors. With the aid of smart devices and internet applications, the author's primary goal is to develop and advance a controlled structure employing sensor nodes in the fields. They are combination of three fragments: hardware, web applications, and mobile applications. Plan and progress in the control hardware box, which is used to gather data on the crops, was the hardware component. The web-based application was next component, which is utilised to modify crop and field information. Data analysis using data mining is used in the component to forecast temperature and moisture for the impending supervision of crop growth. Basically, the final component is utilised to control crop irrigation through a mobile application on a smart device. LINE API for the line application is used to send the notification to the system. The proposed system was executed and verified in Makhamtia District, Suratthani Province, Thailand. The results shown describe that the proposed system is considered for the investment because of less money i.e., $93.25 Dollars approx. per field, but this system is not appropriate for mixed farming. [3]

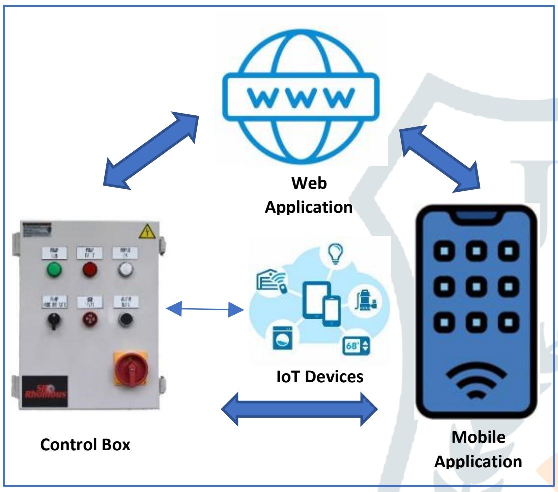

Figure 1: An overview of the system [3]

The biggest issue in agriculture right now is how to use scarce resources like water and labour, which are in limited supply in many regions of the country. The agricultural industry has not had any significant technological advancements compared to other sectors. Regular monitoring of the agricultural system is required. The framework developed was utilised to fully automate the agricultural sector and get rid of waste. It is essential to find a solution in order to recover the domain and put it back on a better growth trajectory. A structure for an electronic farm application centred on modules for knowledge management and monitoring is suggested by the study. To make good choices, agriculturalists require data during the whole farming cycle. In the current framework, Internet of Things-based developed systems are unreliable due to their dependency on network connection modules. Search inquiries are helpless due to their inability to deal with farmers' limited knowledge and the fact that they were made to serve a certain category of crops or location. Due to the automation's ability to operate in both online and offline modes, the suggested approach here solves challenges. The need for water is not constrained by earlier farming methods. However, the system avoids these issues by using evapotranspiration to calculate water requirements, which reduces water use. The developed framework recommends farmers to switch out the current systems with routine activities based on the yield by swapping the current systems like KB Management, Expert Knowledge Systems and Advisory. [4]

Indian agriculture depends on rain during the monsoon season. The production of food by the agricultural sector is limited by monsoon uncertainty. Every season of the year, irrigation is crucial for agriculture because rainfalls are unpredictable during monsoon. In India, 80% of the nation's rainfall occurs from June to October. Therefore, during the remaining months, it is crucial to irrigate fields securely and efficiently. The authors discuss a case study involving an intelligent irrigation system. The existing insecure HTTP protocol was replaced with the lightweight MQTT (Message Queue Telemetry Transport) protocol to build a smart watering system. The protocol named as MQTT is approx. 23% more energy-efficient, 15% faster, and secure when related to other protocols.

The data on moisture and temperature are gathered and achieved using the Amazon cloud. The statistics is analysed using the Weka programme. The main influence of the proposed work makes use of the simple MQTT protocol to provide efficient and secure user-device and sensor connection, hence enhancing the functionality of the smart irrigation system. The WEKA tool is used for analysing sensor data and to control the water supply to plants and help schedule the proper flow of water just when it is required by plants. The suggested remedy is not intended to work with irrigation systems that are completely automated. [5]

The first goal is to create an IoT-agriculture framework for sugar cane production that enables real-time monitoring of agricultural resources such as farmland, water supply, plant type and state, temperature and humidity, use of organic insecticides, machines for harvesting and cultivation, and tracking of labourers on the farm.

The suggested framework combines a large quantity of devices to form a surveillance and tracking network by integrating an existing model. In order to observe the environment of the crop, RFID tags are attached to soil and other agricultural resources as sensor devices. These RFID tags provide real-time information about crop moisture, humidity, leaf moisture, etc.

The stakeholders receive this information in a vibrant flow, which immediately establishes the problem's location. The IoT-Agriculture sector primarily focuses on monitoring various elements like soil, weather, environment, plant nature, water supply level control, and pesticide level. In IoT-Agriculture, there are numerous of smart and remote-control production tools will be used to generate data from the farms.

With the help of this model, decision-makers can swiftly assess the agricultural field's current state of production and decide whether to make any necessary immediate changes. The three entities (government, farmer, and producer) are linked together in a single network, which is the model's main benefit. The suggested approach is sustainable in a number of ways. By having access to real-time data from the agricultural field, the government can readily decide how much money to set aside for sugarcane production during a given time.

The suggested model shows the wide area of damage in the agriculture area even if there is any loss or damage as a result of a natural disaster. The government can readily decide how much money it will pay for the affected region based on the range. The mills that manufacture sugar can readily predict the demand and supply of the crop for a certain period of time, as well as their own manufacture capacity and economic return. This model has not yet been found to have any flaws. [6]

The quality and safety of food have always been in high demand because it is the primary source of energy for living things throughout human history. Incorporating IOT into the food supply chain (FSC) is thought to improve standard of life by monitoring food conditions and live-sharing the resulting data with customers or FSC managers. The goal is to examine the potential use of IOT in agriculture to monitor safety and quality of food. The proposed IOT technologies are made up of many distributed resources that can be chosen based on the requirements of various users and organisations worldwide. The resources of IOT may be divided into three categories by taking into account the view of IOT technology, which focuses on technological implementation. These three layers are thought to be the fundamental IOT architecture layers. These layers are the application layer, network layer, and sensor layer that are depicted in the picture. These layers carry out their individual tasks and share data. The primary benefit of this concept is that it can ensure food safety throughout the entire food supply chains (FSCs), which comprise food manufacture, processing, packing, transportation, storage, and consumer sales. [7]

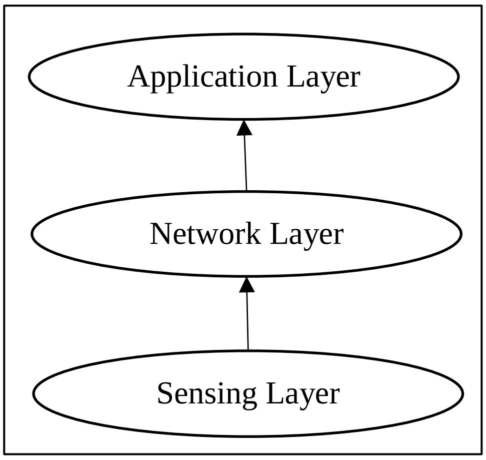

Figure 2: IOT architecture layers from the viewpoint of technical implementation. [7]

Here authors outline research topics related to safety and confidentiality in the context of IoT-based green agriculture. IoT-based smart agriculture has given farmers the ability to increase crop yields, maximise irrigation efficiency, and lower operating expenses. The agreement algorithms for blockchain-based solutions are described by the authors, along with how they will be modified for Internet of Technology-based green farming. It is a clever agricultural solution that combines farming with cutting-edge digital technology. Precision agriculture, facility agriculture, and contract farming are three features that have emerged as a result of IoT technology. The authors' primary goal is to group risk models against IoT-based green farming into five categories that includes intrusions into personal information, identity theft, confidentiality, availability, and integrity. Machine learning techniques, datasets for intrusion detection, scalability analyses of solutions based on blockchain, how to choose the best agreement algorithm, and the design of useful and well-suited cryptographical protocols are just a few of the difficult research areas that still need to be addressed. cryptanalysis procedures. [8]

This article discusses the promise of wireless sensors and the Internet of Things (IoT) in farming as well as the difficulties that will inevitably arise when fusing this IoT technology with conventional farming methods.

The communication infrastructure, like as base stations or Wi-Fi, is particularly restricted in agriculture, which restricts the IoT's capacity to advance in this sector. In underdeveloped nations and rural locations, such communication infrastructure and accompanying utilities are significantly worse. UAVs provide an option in this situation since they may visit and interact with the wireless sensors dispersed over broad areas to collect data for further processing and analysis. Furthermore, thousands of hectares of fields can be flown over by UAVs, also known as drones, equipped with sharp sensors and high-resolution cameras. In all applications of agriculture, surveillance plays a crucial role. Therefore, precise data collecting and transmission facilities supported by quick, low-cost, real-time, and extensive monitoring are essential for agriculture output. Currently, satellites and aeroplanes are the primary methods utilised to get aerial photographs of a field area. For a large perspective of a landscape, they are both good, but when it comes to micro views, they have major quality problems. Therefore, when we take into account the micro perspectives, we may overcome— or perhaps eliminate— the aforementioned problems with UAVs that provide an "eye in sky." In order for farmers to take prompt action, UAVs support faster and better NDVI to evaluate crop conditions, such as weed mapping, leaf assessments, etc. All of this leads to the conclusion that every square foot of farmland is essential to maximising crop yield. However, using sustainable IoT-based sensors and communication technology is essential if we are to manage every inch in the right way. [9]

IoT-based WSN has been utilised in agriculture production to monitor yield conditions and automate precision farming utilising a variety of sensors. The proposed framework's main motive is to select the best cluster heads using a multi-criteria choice function. Here, the authors improved the framework already in place by suggesting an IoT-based WSN framework as a smart farming application that consists of various design layers. First, agricultural sensors gather pertinent data and use a multi-criteria choice function to select a set of cluster heads. To ensure reliable and effective data transmissions, the signal to noise ratio (SNR) is also used to monitor the signal strength on the transmission connections. Second, using the recurrence of the linear congruential generator, security is given for data transfer from agricultural sensors towards Source stations.

The results of the simulations demonstrated that the proposed model significantly improved communication performance, with average improvements in network throughput, packet drop ratio, network latency, energy consumption, and routing overheads for smart agriculture of 16%, 38.5%, 13.5%, and 13%, respectively. However, the suggested architecture is incompatible with IoT networks that are based on mobile devices and Intelligent Transportation Systems. [10].

It is predicted that agriculture uses 85% of the freshwater resources available globally, and this percentage will continue to lead due to population expansion and rising food demand. Agriculture will use a significant number of freshwater resources. This necessitates planning and tactics to make wise use of water by applying science and technological improvements. The authors bring out a brand-new smart agriculture system that makes use of IOT, WSN, and cloud computing to assist farmers in creating irrigation schedules for their farms using agriculture profiles that can be customised to their needs. A computerized watering system is created to maximise the use of water for farming crops based on user input.

To control the amount of water, a microcontroller-based gateway was designed with an algorithm based on temperature and soil moisture threshold values. Based on data from the meteorological repository and data detected in real time from the field, this system develops an irrigation programme. This method can advise farmers regarding the necessity of irrigation. The farmers' requirement for a constant internet connection is the main disadvantage in this situation. [11]

By utilising modern informational technologies, crop production decisions can be improved in agriculture. The effectiveness that may be obtained by comprehending and managing the inherent inconsistency found within a farm is undoubtedly increased by precision agriculture. In the agricultural industry, late blight is a deadly disease that damages several crops, including potatoes and tomatoes. By using data gathered about the climatological and soil conditions of the plants, machine learning is using the advantages of precision agriculture to stop the spread of the late blight disease. The algorithm then advises the farmer to take effective steps to stop the impurity as soon as feasible. Internet of technology is also utilised to gather sensor data from the field so that the information and recommendations from machine learning algorithms may be made available on a GUI platform, making it simpler to maintain continuous field monitoring. The authors here suggested a cloud-based IoT platform based on the integration of IoT and machine learning to predict late blight disease in potatoes and tomatoes before the first occurrence. This lowers costs by providing the farmer with an exact threatening communication on the specific time to apply the protective pesticides, helping to save crop manufacture in the infection seasons and reduce the usage of the redundant insecticides. The observed flaw is that it required human intervention to put the action into effect. [12]

This research comes up because farmers demand a novel platform to determine the most efficient choices to monitor and manage their farming fields, particularly for manuring tasks. In traditional farming methods like physical field monitoring, water the farms, detection of pest, testing of soil, etc., farmers monitored the farms and often applying insecticides neither or nor having the information about the quantity of pest to be used to control the effect of crops. So, it is mandatory to enhance the farming production by making the effective use of expertise knowledge by using technology to overcome the damages being done. The author's aim is to guide the farmers by provide the current technologies like IoT, cloud computing and image processing for smart monitoring the agriculture land. To address the problems the authors proposed a model named "AAFAMS" (Automated Agricultural Field Analysis and Monitoring System Using IOT) which is used not only for monitoring the field but also to suggest the farmers about the moisture content in soil and detecting pest. AAFAMS is an automated robot. This model uses raspberry pi and sensors to recover relevant data and helps to provide accurate results. The solar panel is used for energy supply and it also reduces cost to make effective use of natural resources. When compared to electrically battery-operated device as well as helps to get more yield. This model is not able to check the soil quality and sometime generated report is not understandable by the farmers.[13]

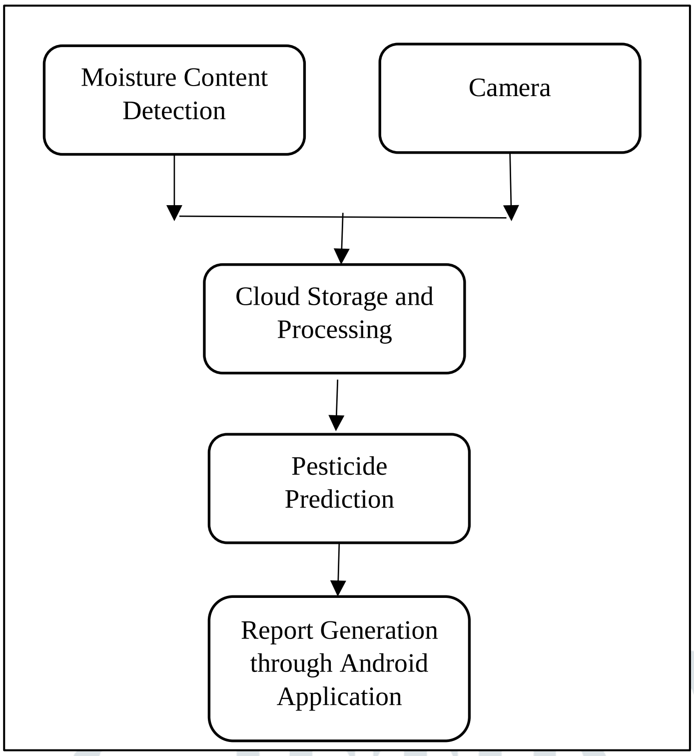

Figure 3: Block Diagram of AAFAMS Model [13]

The authors proposed a model to for water suppling in the farming land when the land is dry without any human interaction and avoiding water wastage in irrigation process, soil parameters can also be monitoring foe example humidity, temperature and moisture level in the soil. The main motive to this model called smart agriculture model is to avoid the wastage of water in the irrigation process. It includes NodeMCU, Arduino Nano, sensors like soil moisture and Dht11, Ssolenoid valves, relays. NodeMCU is the latest version of this system has a benefit is that it acts as two ways i.e., microcontroller and server. This model has multiple advantages and it has cheap installation cost. Farmer can access and control the system using any gadgets like laptop and smart phone. [14]

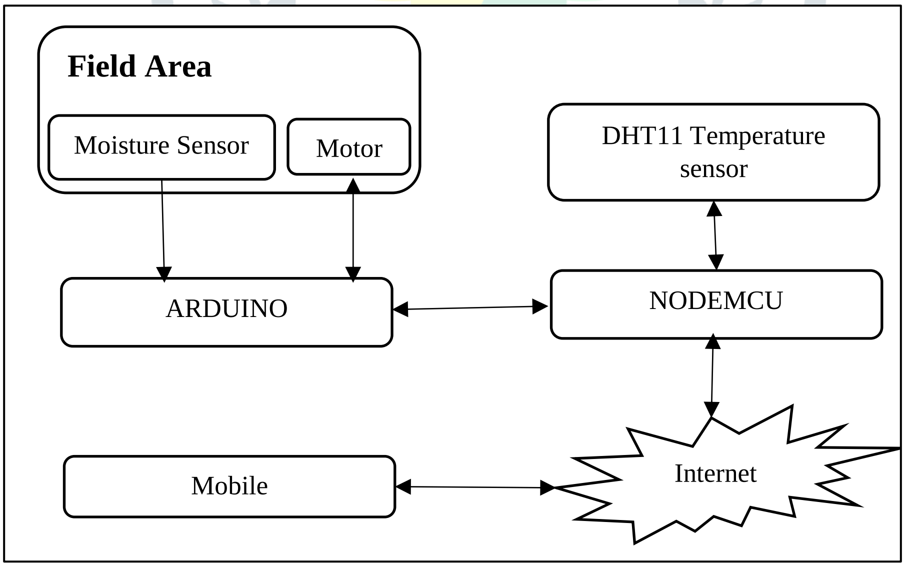

Figure 4: Block Diagram of Smart Agriculture Model [14].

3. Comparison Table

Sr. No.	Author	Model	Purpose	Advantage	Drawback
1	Muangprathub et al. [3]	Control system using node sensors driving agriculture through digital innovation.	Improve the irrigation methods increasing agricultural productivity	Send notification in mobile when field require irrigation	Not appropriate for mixed farming
2	K. Haseeb et al. [10]	An energy-efficient and secure IoT based WSN framework for smart agriculture application	To offering a smart decision for data routing and reducing the ratio of energy consumption with improved data delivery performance in farming land.	Offers safe and secure transmission from farming sensors towards the base station.	The proposed framework is incompatible with IoT networks that are based on mobile devices and Intelligent Transportation Systems
3	G. Sushanth and S. Sujatha [11]	Smart agriculture System based on IoT, WSN, and cloud computing	Creating irrigation schedules for their farms using agriculture profiles	Advise farmers regarding the necessity of irrigation	Constant internet connection
4	Araby et al. [12]	Sensor network based on Artificial Neural Network machine learning algorithm	Predict late blight disease in potatoes and tomatoes	Warning message on the specific time to apply the protective pesticides	That it required human intervention to put the action into effect
5	Kajol R et al. [13]	AAFAMS model	Monitor the moisture content in soil, detect pest.	The solar panel is used for energy supply and it reduces cost	Not able to detect soil quality
6	K. Jyostsna Vanaja et al. [14]	NodeMCU	Supply water when farm is dry without human presence	Avoid water wastage in the irrigation process	Nil

4. Role of IoT in smart agriculture

The IoT is transforming the agricultural industry by giving agronomists a wide range of tools to handle various problems they encounter in the field. Using IoT-enabled devices, farmers can access their farms at any time and from anywhere. Wireless sensor networks are being utilised to monitor the farming land, while sensors and actuators are employed to control farming processes. The farm was monitored remotely using wireless cameras and sensors, which also gathered raw information in the form of images and videos. IoT enables farmers to monitor the state of their farming land using a smartphone from any location in the world. Technologies that are IoT-enabled have the potential to lower crop production costs and boost land productivity [15]. Few roles of IoT in smart agriculture is presented in figure 5.

a) **Crop management:** IoT sensors and RFID chips can be used to find plant and crop diseases. The reader can gather these facts from RFID tags and disseminate them online. The farmer processes this data remotely and takes the appropriate action. This will prevent bugs from damaging the crops. Production tracking and prediction have been crucial in the agriculture sector for providing users with benefits so they can create profitable output while reducing losses.

b) **Irrigation methods:** One of the goals of irrigation systems is to monitor crop water demands based on collected data and control the water flow in accordance with the predicted needs without the involvement of human operators. Field-deployed sensors are used in IoT-powered smart irrigation systems to track soil characteristics, weather and climatic conditions, and farming parameters for irrigation.

c) **Soil management:** The process of managing soil involves measuring several soil properties, including moisture content and pH. IoT sensors make it simple to calculate these parameters. Following that, farmers will implement strategies like fertilisation, drainage, irrigation, and so forth. Finding the best plant breed is aided by soil management. It also aids in determining the soil's need for fertiliser.

d) **Tracking and Tracking:** To remotely monitor soil structure and condition in compliance with crop culture needs, an architecture was created. ZigBee is connected to other devices like CMS, GSM, and GPRS through the use of WSN in order to monitor and recognise real-time data processing. When unanticipated changes occur, an interface for communication with ARM is offered by GPS and alerts the farm manager so that the farmers can respond appropriately.

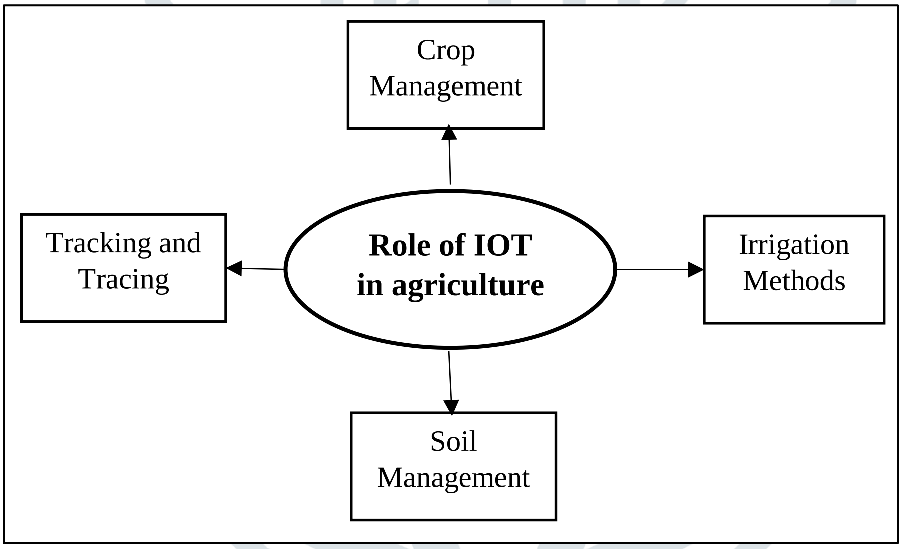

Figure 5: Role of IoT in agriculture

Conclusion: Remote sensing in agriculture is changing the way data is collected from various nodes on a farm. IoT-based remote sensing uses sensors installed alongside farms, such as weather forecasts, to collect data, which is then transmitted to analytical tools for analysis. Sensors are devices that detect anomalies. Farmers can use the analytical tracker to monitor crops and take action based on insights. This paper has presented a literature review that presents a discussion on selective high-quality research articles published in the domain of IoT-based agriculture. In this paper various models and architecture presented by different authors has been discussed with their advantages and disadvantages. At the end the comparison analysis of various models has been done.

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