

An Analytical and Systematic Review of Smart Farming's Challenges and Opportunities

Navneet Kaur, Professor, Sri Guru Tegh Bahadur Institute of Management and Information Technology, Delhi, India
drnavneet.sgtbimit@gmail.com

Harneet Kaur, Assistant Professor, Public College Samana, Patiala, Punjab, India drharneetkauraurora@gmail.com

Nehu Gumber, Assistant Professor, Sri Guru Tegh Bahadur Institute of Management and Information Technology, Delhi, India
Nehugumber1@gmail.com

Abstract: Various industries have become more financially accessible due to technological advancements in various circumstances. Integrating Internet of Things technology in crop cultivation has shown benefits for multiple industries, such as agriculture and food production. The review paper below presents evidence of Internet of Things technology's impact on intelligent agriculture. This paper aims to review smart agriculture systems utilising Internet of Things-connected devices. The report has examined various essential aspects of smart agriculture and the advantages of Internet of Things technology. The review paper thoroughly discusses the different elements of the Internet of Things (IoT) technology. The application was found to have several areas for improvement, such as high cost, knowledge gap, and significant energy consumption. A rational discussion addresses the possible solutions to the raised issues. On the other hand, secondary qualitative methods, which use qualitative data, have facilitated discussions about the needs of smart agriculture. The paper shows significant knowledge about implementing Internet of Things systems in intelligent agriculture.

Keywords: *IoT, precision farming, challenges in precision farming, opportunities in precision farming*

1. Introduction

Advancements in various technologies have enabled other sectors to improve their operations and enhance productivity. Various technological advancements have a discernible impact on increasing overall yield. The review paper focuses on smart agriculture and the utilisation of IoT. Precision agriculture, also called smart agriculture, utilises advanced calculative technology to calculate and pre-determine the outcome of the cultivation process. Simultaneously, utilising technological assistance to increase yield requires a relatively minor budget. Agricultural risk can be forecasted and controlled effectively with dependable outcomes. This analysis systematically examines the utilisation of IoT devices in agriculture. Furthermore, specific outcomes are expected from the examination of previous articles.

2. Methodology

The methodology of an empirical analysis encompasses all the steps taken to produce results. The method examines various factors that influenced the outcomes of the study's goals. A secondary qualitative methodology was used to create a review paper. Information from previous literature was collected and thoroughly examined to understand the utilisation of IoT devices in accurate agriculture. The impact of IoT devices is analysed using qualitative and quantitative data collected from previous literature analysis.

The secondary data has been pre-verified, making the study's outcome reliable [5]. Furthermore, secondary qualitative methods provide an in-depth view of the utilisation of IoT devices in agriculture. A detailed analysis of the use of IoT devices in agriculture was presented.

3. Elements of smart agriculture that aid in achieving a better yield

Understanding the components of smart agriculture is crucial for utilising IoT devices to enhance agricultural productivity and for gaining a clear comprehension of the operational process [6]. IoT devices operate within a structured protocol to gather and analyse information on various factors. Figure 1 depicts a detailed portrayal of the utilisation of IoT devices in agriculture. 70% of the IoT devices used in precision agriculture are primarily for monitoring purposes [7]. Furthermore, 25% of the usage is attributed to managing the agricultural process. Simultaneously, 5% of the users are observed to be actively monitoring [8]. Thus, utilising IoT devices is crucial for monitoring various cultivation-related factors. Therefore, decisions are made based on the systematic analysis. Smart agriculture aims to enhance agricultural productivity through technology and data-driven approaches. Furthermore, in smart agriculture, various components contribute to improving crop production.

3.1 Understanding and managing soil health:

Farmers can comprehend soil quality to assess soil moisture, nutrient levels, and pH, which is crucial for enhancing agriculture. Thus, sensors can impact soil conditions through a data-driven approach. Furthermore, intelligent farmers rely on conventional methods to gather extra data. Therefore, with this information, they can adjust their fertilisation and soil management methods to achieve optimal plant growth and higher yields. Furthermore, comprehending soil quality is crucial for understanding the development of crops [10]. Crop growth flourishes in optimal soil conditions while maintaining the nutritional quality of the crop. Plants obtain all essential nutrients and water from fertile soil. The plants derive structural support from the soil.

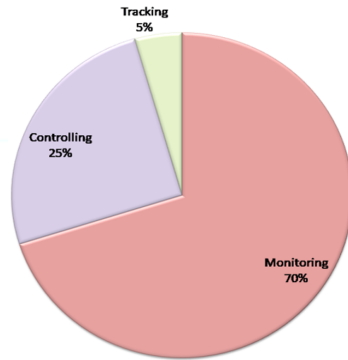


Fig. 1. Use of IoT devices in different domains of agriculture [8]

Thus, by comprehending the soil, farmers can ensure optimal conditions for plant growth, leading to increased harvests. Furthermore, a more thorough understanding of soil quality can facilitate the systematic maintenance of soil health using data collected by IoT devices. Moreover, understanding soil quality helps in considering the application of fertiliser to enhance the nutritional content of the final crop yield. Understanding soil quality helps manage fertiliser use, which is crucial for product quality. It is essential to comprehend the soil's water-holding capacity, especially about the plantation. Rice cultivation is carried out in soil with high water retention capacity to create a favourable moist environment [12]. Therefore, it is crucial to consider the sand-holding capacity for this cultivation. Understanding soil quality is vital for soil management and its subsequent influence on the nutritional content of crops.

3.2 Monitoring of crops for risk analysis and management:

Upon analysing previous literature, it was observed that agriculture involves various strata. Furthermore, farmers must progress through multiple stages, from planting to reaching the final harvest [13]. Moreover, specific risks are linked to each agricultural stratum. Risk can be detrimental to the process, leading to a decrease in the yield's quality and quantity. The risk of developing these factors can vary based on the cultivation season. Moreover, unpredictable natural risk factors could exist. Natural disasters are risk factors that cannot accurately predict through manual calculations. IoT technology enables the precise calculation of evidence using relevant data. Furthermore, by utilising the pertinent evidence, intercity can be assessed, and necessary precautions can be implemented.

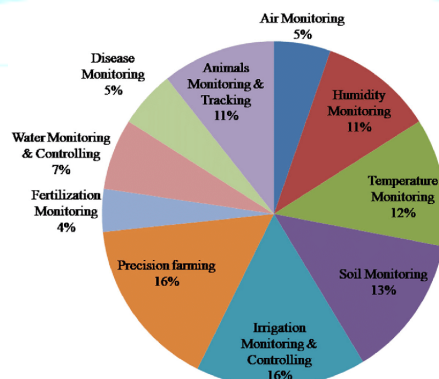


Fig. 2. Use of IoT in agriculture based on the percentage [9]

The focus of IoT devices is irrigation monitoring and management, as well as precision farming, as shown in the figure above. Several examples of IoT applications in agriculture can be understood from the figure above. IoT device monitoring is associated with the planting and growth stage [15]. Past literature indicated that environmental factors inhibited plant growth. Therefore, monitoring factors like air and water quality are crucial for smart agriculture. In the illustration, IoT systems account for 5% of air quality monitoring and 7% of water quality monitoring [15]. Data collected through an IoT system can indirectly aid in the growth of crops.

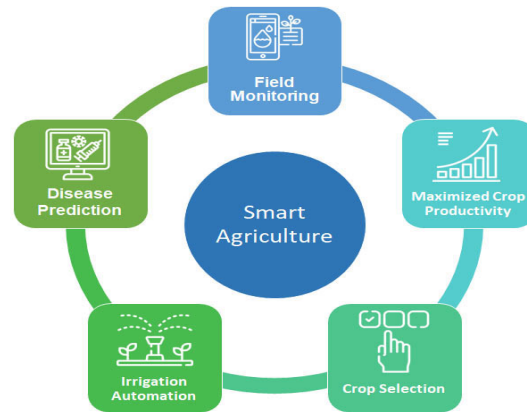


Fig. 3. Elements of crop monitoring using IoT devices [12]

The final yield results from time, and preserving its qualities is crucial for maximising return on investments. Forecasting disease and weather conditions is vital for crop development. The use of fertilisers directly affects the final product [16]. Therefore, precise and efficient fertiliser application can be accomplished by utilising IoT devices in smart agriculture. Though sometimes inaccurate, projections play a significant role in farming and agricultural operations. Accurate calculation of these factors is crucial for farmers to avoid substantial losses. Therefore, these factors play a vital role in comprehending the benefits of having sufficient soil moisture and quality, air quality, and irrigation for crop growth.

Additionally, tracking the development of crops can be highly beneficial for farmers. Various factors, including the quality of the produce, can help assess the risk associated with the growth of the produce. The figure above demonstrates the components of crop monitoring utilising IoT devices [17]. Choosing a crop is a component of crop monitoring. Furthermore, selecting the appropriate crop according to the plant's quality and characteristics is crucial. Environmental factors significantly influence crop development. In smart agriculture, crops are chosen based on factors that support the overall growth of the plant.

Therefore, IoT devices can help select superior seeds for planting [18]. Furthermore, consistent monitoring can be conducted during the growth phase to anticipate any potential diseases affecting the plants. One can achieve a comprehensive disease prediction that enables timely action.

3.3 Planning and controlling the irrigation system:

Plant cultivation requires irrigation and watering, subjective factors determined by the specific plant's needs. Some plants are affected by the quality and quantity of water. *Oryza sativa*, or rice, requires varying amounts of water depending on the growth stage. The basin irrigation method is employed for rice cultivation. Creating shallow, flat basins in the ground to retain water for agricultural irrigation is crucial for basin irrigation. Simultaneously, regulating the water level for cultivating water crops is essential. This method is commonly employed for watering high-water-demand crops like rice, especially in areas with mostly level land. Therefore, incorporating IoT-based devices can establish a more efficient irrigation system for this farming technique. Figure 4 depicts a scaled-down replica of an Internet of Things (IoT) enabled irrigation monitoring system. The above model provides a detailed insight into IoT-based systems. The Raspberry Pi 3 was utilised as the controller for the water-dripping system. Additionally, the unit serves as a processing unit for the Internet of Things irrigation monitoring system, assisting in data processing. The VH400 moisture sensor measures and records binary data of the volumetric water content of the soil, as depicted in the figure above [18].

Furthermore, an Internet of Things (IoT)-enabled weather station computes the Evapotranspiration (ET₀) value to ascertain the water consumption of crops. The Raspberry Pi is connected to the YF-S201 flow metre sensor to monitor the plant's water consumption accurately. The connection was established using an ESP8266 NodeMCU, enabling collecting all metric information for the observation. Utilise the data to enhance decision-making and actions using the scheduling algorithm integrated into the Raspberry Pi. This sensor quantifies the water utilised for irrigation during each irrigation cycle.

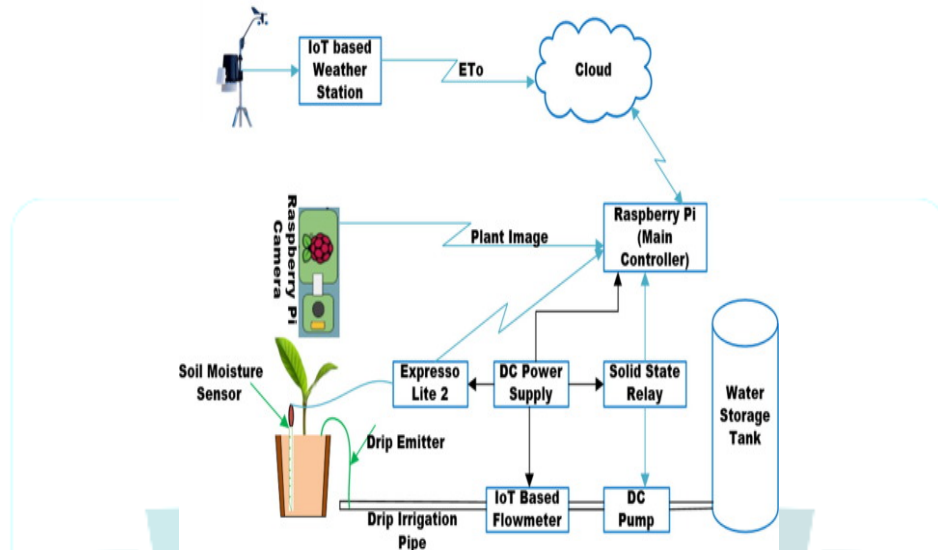


Fig. 4. A miniature model for the irrigation system [11]

The following equation determines the hourly calculation of the water system:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T + 273} U_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)}$$

Where,

- T*: average daily air temperature
- U₂*: wind speed recorded at a height of 2 metres
- R_n*: Solar radiation reaching the soil surface
- G*: density of soil heat flux
- Delta*: gradient of the pressure curve
- Gamma*: Psychometric Constant
- e_s*- *e_a* and the saturation vapour pressure deficit inputs

A comparable extensive system can be constructed to analyse the systematic needs for rice cultivation. An IoT-based system can improve irrigation by monitoring soil water levels for plants that require limited water and have high economic value. An enhanced system can be attained by integrating IoT with irrigation. Furthermore, smart irrigation systems use sensor data to deliver the appropriate amount of water to crops accurately. Furthermore, excess water is managed based on actual needs, which leads to improved plant growth. Precise irrigation leads to healthier plants and higher yields by preventing over-irrigation, reducing water waste, and protecting against water stress.

3.4 Making decisions based on historical information:

Upon analysing the literature, it was observed that the decision-making process is a crucial element of agriculture. During cultivation, various unforeseen circumstances may arise, and the success of the crop relies on decision-making. Thus, a more informed decision can be made by analysing historical data and information collected for the IoT system. Furthermore, utilising IoT systems and the gathered data allows for analysing all relevant factors [22]. A more informed decision can be made using the collected real-time data. Smart agriculture relies on data-driven decision-making, utilising the Internet of Things (IoT) to

gather and analyse data from various sources. Moreover, real-time data assists in making decisions according to specific circumstances [23]. This strategy transforms traditional agricultural methods by empowering farmers to make informed decisions, allocate resources efficiently, and boost production.

Figure 5 displays a framework for data-driven decision-making. The first two blocks in the image depict the development of the mustard leaf plant and IoT monitoring for data collection [24]. The figure serves as the foundation for the data-driven modelling technique. Pre-processing blocks are used to remove unnecessary trends and means from the data to prepare it for a successful model. Additional blocks demonstrate how the model structure aligns with the prepared data and how the model is validated based on performance metrics. The study also calculated performance metrics like mean square error (MSE), final prediction error (FPE), and estimated model fit [24]. Systematic information helps in analysing a comprehensive understanding of the current situation.

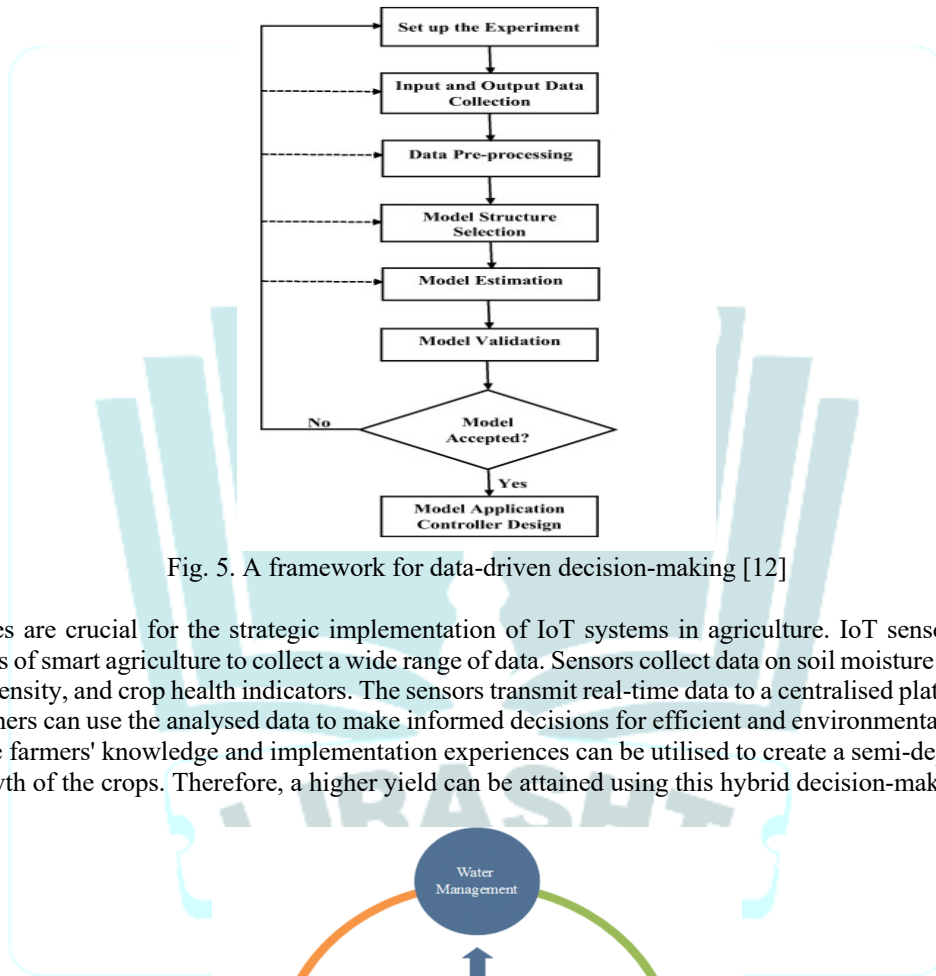


Fig. 5. A framework for data-driven decision-making [12]

Effective strategies are crucial for the strategic implementation of IoT systems in agriculture. IoT sensors are strategically positioned in fields of smart agriculture to collect a wide range of data. Sensors collect data on soil moisture levels, temperature, humidity, light intensity, and crop health indicators. The sensors transmit real-time data to a centralised platform for processing and analysis. Farmers can use the analysed data to make informed decisions for efficient and environmentally friendly farming methods [26]. The farmers' knowledge and implementation experiences can be utilised to create a semi-dependent system that enhances the growth of the crops. Therefore, a higher yield can be attained using this hybrid decision-making system.

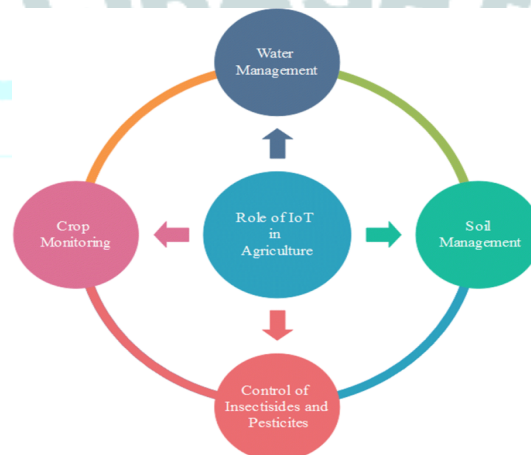


Fig. 6. Role of IoT-based systems for smart agriculture [10]

Data-driven decisions help prevent disease and control pests. Desires can significantly impede crop cultivation and potentially reduce yield. Therefore, any departures from the optimal metrics ranges can be readily identified through IoT devices [27]. Moreover, IoT devices that assist in monitoring crop health indicators like internal temperature and air humidity help make informed decisions. Determiners can assist in analysing the initial phases of the disease, which are essential for safeguarding the ultimate yield [28]. Farmers can take targeted action with early diagnosis and apply pesticides only when needed. Furthermore, the regulated application of pesticides reduces their adverse impact on the environment and the end product. Thus, it is possible to maintain both crop production and nutritional value.

4. Relevant elements of IoT that aid in Precision Agriculture

Devices based on IoT have complex networks of different components that aid in the process of smart agriculture. Such complex networks related to IoT systems aid in the process of collecting reliable information that data drives decision-making. There are different mechanical components, such as drones and sensors. In addition, there are different software components, such as artificial intelligence (AI). To precision in agriculture, all the components work coherently and systematically. Following, a discussion of the elements and IoT bases of smart agriculture systems are presented:

4.1 Sensors: Sensors are essential for gathering information regarding crops and environments. For instance, sensors aid in gathering information regarding the soil, Air, and pollution. Sensor nodes are equipped to track various variables to achieve information regarding the crop's fields [29]. Additionally, the implication of nodes aids in determining soil moisture, temperature, humidity, and light levels based on which appropriate decision-making can be achieved. These sensors offer farmers real-time information regarding the crops. Thus, pest control, irrigation, and planting choices can be made. Therefore, by gathering real-time data from the environment, crops, and animals, sensors are crucial in allowing IoT devices for smart agriculture [30]. Moreover, these sensors offer insightful data for farmers to optimise resource allocation. Additionally, the holistic development of agricultural practices helps to make well-informed decisions. Based on the implication, different sensors are used in smart agriculture. For instance, the leaf monitoring systems' soil monitoring and water content required different sensors.

4.2 Databases and cloud computing: In the agricultural ecosystem, databases act as stores for vast volumes of data gathered from diverse sources. Databases mainly comprise information collected by sensors that keep records of the temperature, moisture in the soil, crop health, and more. To enable effective recovery and analysis, databases arrange and store this data in organised ways that aid in further study of the collected information. Farmers have access to historical and current data to make educated decisions regarding planting, irrigation, pest control, and other issues [31]. Databases make it possible to build prediction models that, based on previous trends, estimate crop yields, disease outbreaks, and the best times to sow. Farmers are given the tools to use such data to benefit the yield. Additional databases are associated with cloud computing technology and form the foundation of smart agriculture systems.

Smart agriculture systems manage a vast amount of information, which is processed, analysed, and disseminated using cloud computing to improve the yield. as the foundation. It has numerous significant benefits for agricultural systems [32]. For instance, the scalability of the resource allocation is directly related to cloud computing. Cloud technology benefits smart agriculture, as data flows might differ significantly depending on the crops' planting, growing, and harvesting seasons. In addition, cloud computing for smart agriculture primarily impacts data processing and accessing real-time data. Therefore, a better, cost-efficient system can be delivered with the help of an IoT system for agriculture [32]. Furthermore, environmental sustainability is a significant factor that impacts the quality of the produce. Hence, with the monitoring system, achieving ecological sustainability during the cultivation process is possible.

4.3 Use of actuator network: Sensor technologies directly send information to the actuator networks to control the actuator for agriculture. For instance, different machinery and valves are actuators connected to the actuator networks [33]. Therefore, with actuator networks and sensors, remote control of mechanical parts can be achieved. Moreover, such sensors act as the primary source of information based on which actuator networks work. Thus, it can be contemplated that actuator networks are essential for promoting smart agriculture as they convert data-driven insights into beneficial results [34]. These networks are made up of gadgets and mechanical components that use data from sensors and other data sources and may automate and regulate physical activities in the agricultural environment.

Figure 7 illustrates a model for actuator networks for smart agriculture. The actuators are attached to the plant, and different sensors are connected to the same [35]. As can be seen from the above illustration, the sensors gather real-time information

from the plants and send that to the controllers as input information [35]. Furthermore, the data is processed and compared with the historical information stored in the databases. After processing the information, output information is generated and sent to the actuators. With the help of real-time information actuators, parts transform the output information into action for the agriculture process. Actuators are further for the process of modifying environmental factors. In a controlled setting, actuators can regulate the temperature, curtains, and ventilation systems to facilitate the ideal atmosphere for plant growth.

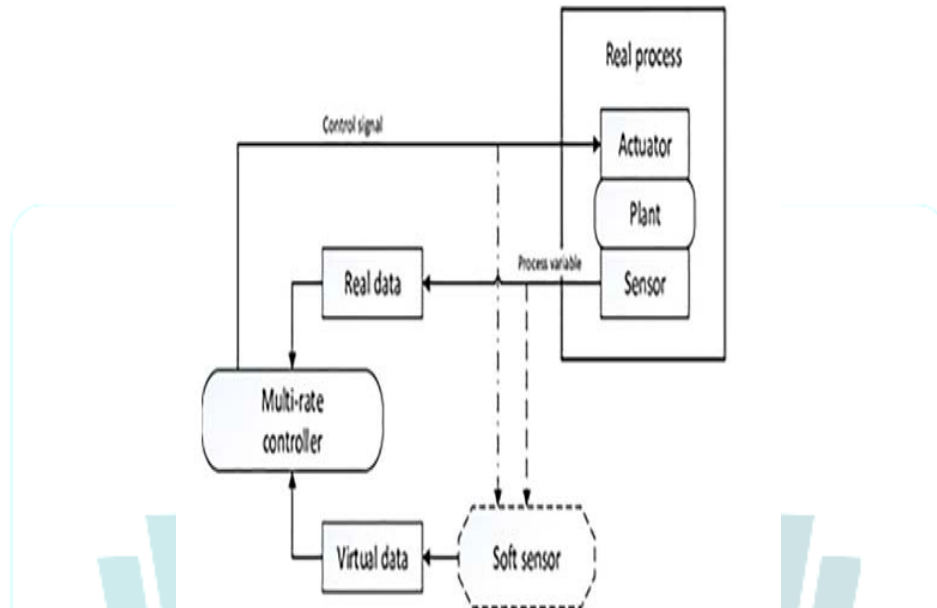


Fig. 7. Framework for the use of actuator network [19]

4.5 Establishing wireless communication for the elements: The basis of communication for IoT systems and networks depends on wireless communication systems. Wireless communication facilitates control for the different elements and works as a medium for transferring input and output information. Additionally, a collaborating system with edge computing systems reduces latency, thus improving the efficiency of ATE systems [36]. Edge computing involves processing data closer to its source to minimise latency and improve real-time decision-making. Therefore, edge devices analyse and transfer information through locally interpreted sensor data and wireless communication systems to deliver quick insights without only depending on centralised cloud processing. Hence, the smart agriculture wireless communication process is one of the significant elements that will allow the IoT system to work efficiently. Furthermore, edge computing is one of the considerable elements for processing information in local servers. Thereby, decisions such as water retention, fertiliser use, and providing nutrition to the soil can be made quickly.

4.6 Customised machinery, Unmanned vehicles, and drones: Technology such as drones and unmanned vehicles play a pivotal role in using IoT devices for smart agriculture. Additionally, the collected data can predict the agriculture process [37]. Fields of agriculture are imaged in high detail with unmanned aerial vehicles that include cameras and sensors. Moreover, the collated information is then used to assess the health of plants and track agricultural production. Furthermore, during the analysis, it was noted that there are specialised needs for smart agriculture [38]. Moreover, the needs of the cultivation process are subjective and depend on the crop. Hence, such needs can be catered to by customised vehicles. Connecting such a mechanism with the IoT network helps in achieving machine operation.

In Figure 8, a customised smart fertilisation system is demonstrated and controlled with an IoT network. Some sensors collect information regarding soil health and plant needs [38]. The information is collected from the sensors and processed in the data processing servers. The collected information is then analysed and converted into the output information. Such output information further facilitates spraying motion to the PID controllers, and based on the information, fertiliser composition is sprayed in the field. Such customisation can be based on soil health or plant requirements. Moreover, such systems can be modified based on the collected information from sources.

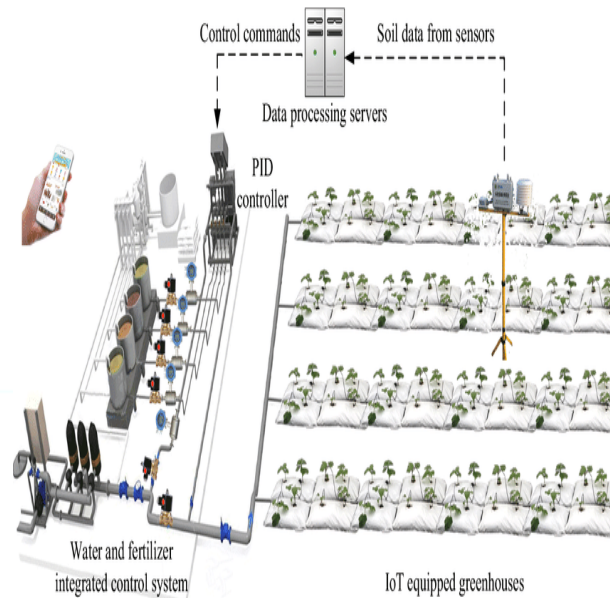


Fig. 8. Customized smart fertilisation systems [20]

5. The utilisation of IOT in the process of Farming

5.1 Light control: The smart farming system is based on technology. Implementing this type of modern farming technology is specially prepared to solve problems related to agriculture. This technology is more focused on in-house agricultural practices. Farmers adopted this technology to practice farming in disastrous areas unsuitable for agricultural practices [39].

The light control system of agriculture could be manipulated using internet-based connections. This increases the usability of modern technology and helps farmers control all types of farming-related technology. IOT-based technology allows users to control all activities from distant places through a high-speed internet connection. Modern technology helps forecast plant and vegetable growth in different stages. This agriculture system helps increase the production rate of plants in all areas [40]. This is the ultimate future of agriculture as it saves the plants from disastrous weather conditions.

In modern technology, development farming activities are controlled by artificial technology. The light control system is used in IOT-based farming to prevent the plants' photosynthesis processes. This increases the growth rate of the plants and helps grow the plants in cold climatic conditions [41]. Thus, the light-controlling system helps to manipulate the growth of the plants. Modern IOT-based farming systems include different active sensors in the firm, such as cameras and sensors for measuring the plant's development. Lights in the in-house plantation increase the temperature and dryness and help to manipulate the real weather effects in the firm.

5.2 Temperature control: The temperature-controlling system of agriculture helps to increase or decrease the firm's temperature rate. This type of practice can be continued in the in-house farming system. This system is mainly controlled using effective lights and an air conditioning system. The effectiveness of the temperature system control has been described below.

This technology helps human beings practice plantation work anywhere in the world. Through this system, farmers can grow a variety of plants, increasing the availability of different types of vegetables and costly items. The development of IoT-based farming technology improves people's incomes as it helps grow various kinds of plants. Thus, the temperature-controlling system is an essential feature of modernised farming technology, affecting the plant's growth. This type of technology has been developed to support farming processes and reduce agricultural destruction.

Table 1 represents the different effects of temperature on plants. Other suitable temperatures for various plants are divided according to the needed temperature, such as cold-climatic plants, hot-climatic plants, evergreen plants, and so on. All plants can be planted using modern IOT-based farming technology, which helps control and change the in-house weather [42].

Table 1. Effect of the temperature control system on the plants and the farmer’s practices

Effect of temperature	Actual benefits of the farmers
Increase the plant’s growth	Excessive growth of the plants increases the farmer's opportunity to continue the practice of repetitive farming
Helps to generate different kinds of plants	This increases the opportunity for the farmers to grow any kind of plants that generate more revenue
Decreases the plant's diseases	This reduces the expenditure behind the maintenance of the plant’s health
The temperature control system included the air moisture.	This effect on the humidity presence in the air helps to manipulate all the things related to the plant’s growth

Figure 9 represents the effect of the IoT-based plantation on farming activities. The utilisation of IoT-based technologies is different from one stage of agriculture to another as this technology is generally 25% effective in the pre-harvest processes of agriculture, 35% effective in Agri-warehousing, 37% effective in the processing, and so on [43].

Modern technology also supports the supply chain and increases the overall productivity of agriculture. This increases the awareness of the different agriculture-related activities, such as increasing the 100% awareness in the supply chain [43]. This means this reduces the wastage of the plants and increases the rate of profitability in agricultural practices. This modern practice of agriculture helps increase production quantity and quality.

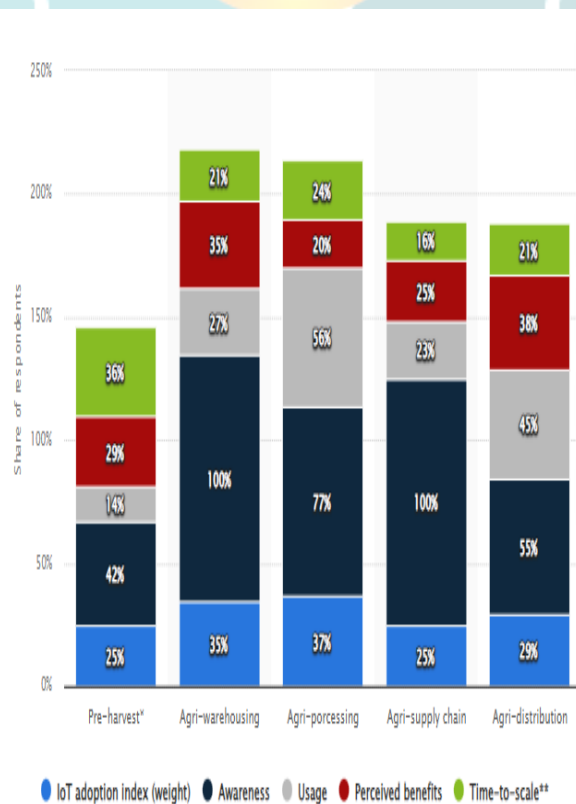


Fig. 9. IoT-based plantation and its related facts [17]

5.3 Soil condition and soil moisture: The main thing plants need is soil, as they get all the nutrients and minerals from it. In the modern farming system, artificial soils are used to increase the growth rate of the plants. Soil condition and soil moisture help the plants get an adequate amount of minerals. Farmers use different kinds of fertilisers to increase the amount of minerals [44].

IOT-based farming includes sensors to measure the soil fertility level and manipulate the soil moisture. Farmers can control soil moisture with this modern farming technology. The requirement for soil moisture generally differs from one type of plant to another. Different traditional processes increase the soil condition, such as crop rotation, conservation tillage, cover crops, etc [45]. In modernised farming technology, artificial soils have been used, which are comparatively fertile and full of nutrients. The IoT-based sensors are used in the soil to measure the hydrological factors of the soil, such as soil fertility, permeability rate, hydration, and absorption.

This increases the awareness of the farming system and increases the production quantity. The main difference between IoT-based farming and traditional farming helps to understand the importance of IoT technology in farming processes.

Table 2 represents the difference between the two agricultural processes. It shows that the soil monitoring system of IoT-based agriculture is fully digitalised technology that controls the different sensors. This is mechanical-based farming, in which the farmers control all the interrelated farming activities using IoT technologies.

Table 2: Difference between IoT-based farming and traditional farming

IoT-based farming	Traditional farming
Uses a modern technique to increase the moisture level of the water	This uses traditional irrigation technology
This system included different sensors to inform the moisture level and other conditions of the soil	Farmers used to visit for checking the moisture level of the soil
The ingredients used in the soil are artificial	Here natural and artificial components used in the soil
Monitoring systems control soil fertility through the modern system	The traditional agricultural system is based on the manual system

5.4 Infection monitoring of the plants: IOT-based farming creates a recognition framework through which it collects data with the help of some sensors. These sensors check plant leaf temperature, humidity, and colour, which help to formulate data, and through analysing the data, it is possible to identify plant decay [46]. IOT-based farming allows farmers to monitor field conditions and detect plant diseases from anywhere. It uses technologies like RGB imaging, thermography, and hyperspectral sensors to detect plant decays earlier and helps enhance sizeable commercial farming. IOT-based farming uses a wireless sensor network to monitor plant diseases and provide sustainable development in agriculture. This system can detect multiple plant diseases within a certain period and provides flexibility in various application areas [47].

IOT-based farming has become popular in industrialised countries, bringing progress in the agricultural field and generating revenue in the market. Farmers benefit from this system, which helps them identify plant diseases and minimises costs and environmental effects. IOT-based farming uses low-power cameras to detect plant diseases, and data has been collected through this system. These data are sent to the centralised platform, which helps the farmers detect the exact location of the plant disease and take strategies for plant growth development.

IOT-based farming also uses high-power thermal sensors to detect plant diseases. This sensor measures the light reflected from the surface. The spectral signature represents reflected light energy in a distinct amount; every plant has a spectral spectrum. This spectrum is recorded in spectrometers, which help detect plant diseases by changing their range [48].

This method is considered a highly effective method for enhancing the plant's growth and helps detect diseases that are not visible to the eyes. IOT-based farming uses fluorescence parameters to measure a plant's chlorophyll and compare the affected plant leaves with healthy leaves. The changes in chlorophyll pattern in the leaf indicate the diseases of the plant, and through this method, farmers can detect the decay of the plant. Acoustic sensors also give an advantage in preventing plant diseases, and this method detects the sound waves of insects [48].

High sound waves indicate the highly affected plant area with bugs, which helps the farmers detect the location of the affected plant and increase its quality. IOT-based farming gives farmers an advantage in monitoring plant health from several locations and increasing productivity without hampering environmental health.

The implication of IOT-based farming in integrated pest management brings an opportunity for farmers to implement automation services. This automation helps reduce the time for manual data measurement and helps farmers detect plant diseases instantly. IOT-based farming helps farmers monitor plant conditions in different fields and develop instant strategies for improving plant health. It helps increase productivity as well as the quality of the plant.

5.5 Measurement of CO₂ levels: Modern technology has been developed to measure the firm's CO₂ level. The CO₂ level is essential for increasing the production quantity of the farming processes [49]. The volume of the Co₂ exerted by the firm could be measured using different sensors. The importance of measuring Co₂ levels is high as this gradually increases in the firm. The sources of the firm's CO₂ are listed in the following table.

Table 3 represents different sources of CO₂ gasses from agricultural procedures. The amount of CO₂ could be measured using nondispersive infrared or electrochemical technology. This helps measure the CO₂ concentration and indicates when the level of CO₂ exceeds the normal condition [50]. This increases the safety of the agricultural process as the higher volume of CO₂ negatively impacts the plants.

Thus, modern technology is essential for increasing safety, profit, and production quantity. This reduces the chances of losses from agricultural practices and increases farmers' interest in continuing agrarian activities. IoT-based machinery decreases farmers' efforts and helps them control all agricultural-related activities from distant places [50].

Table 3: The components and the processes of agriculture produce the CO₂

Number of days the firm engaged in the agricultural procedures
Weight of the disposal of the firm
Amount of wastage and biological wastage produced by the plants
Quantity of fertilizer used in the agricultural field
Quantity or weight of the harvested product
Number of decomposable products

This technology is based on the internet connection, and a high-speed internet connection is mandatory for processing all the systems. This technology has increased the value of agricultural activities, although agriculture is a primary sector activity. This development helps humans produce crops in different types of barren lands and increases the utility of those places.

6. Problems of using IoT for smart agriculture

At teatime, after reviewing past articles related to smart agriculture, it was noted that there are specific problems in the implementation process of IoT devices for smart agriculture. Although the Internet of Things (IoT) has a lot to offer smart agriculture, several issues must be resolved to implement it effectively. The following discussion systematically addresses the identified problem.

6.1 Precision and accuracy of the IoT devices are the issues that can hinder the crop:

The technological advancement of IoT devices is relatively new, and the implications can be identified in the trial phase. Therefore, achieving precision is a significant issue that directly impacts the accuracy of calculating smart agriculture. In addition, such faults in the system can hinder production and final yield [51]. Therefore, accuracy is a significant factor in IoT-based smart agriculture. In addition, the process of smart agriculture is associated with data inputs. Moreover, IoT systems are compactly interconnected, a significant risk for agriculture.

For instance, sensors are responsible for collecting relative information from the field. In addition, based on the collected information, other systems work and provide output data to the actuator network and mechanical parts work based on the same [52]. Henceforth, if there is a problem in the sensor when collecting information from the field, the prediction and calculation of the input data can be impacted; thus, the outcome can be affected as well. Such glitches in the output information could hinder the growth of the plants. Following this, the quality of the final yield can be impacted.

6.2 The high cost of implementation and maintenance hinders the initial implementation of the IoT system for Smart agriculture: There are different components related to IoT-controlled smart agriculture. Additionally, each element has high initial costs that can hinder the field implementation process.

Table 4: Approximate cost of some IoT devices used for Smart Agriculture

IoT devices	Used for	Approximate cost
Sensor for temperature monitoring	Controlling climate, Monitoring the air and soil temperatures	10 to 50 USD per sensor
Sensor for monitoring soil moisture	Monitors the moisture level of soil for smart irrigation	20 to 110 USD per sensor
System for controlling Irrigation	Provides an accurate flow of water when it is required	200 to 500 USD per controller
The sensor of image sensing and camera	Provide visual information for analysing the physical features of the crop	150 to 600 USD per sensor
Water quality and pH sensors	Monitoring the quality of water and pH level of water	20 to 90 USD per sensor
Infrared system and remote control	Control the system remotely	20 to 100 USD per controller
Plant and soil nutrients sensors	Measured the nutrients in the soil for better produce	50 to 200 USD per sensor

Table 4 presents information regarding the cost of some of the essential components. Each component is comparatively on the costlier side. Additionally, the above table presents information regarding a single sensor; however, the number of sensors depends on the use objective [53].

Therefore, considering such factors, a significant cost can be contemplated for smart agriculture. In addition, other elements, such as drones and unmade vehicles, are used in IoT technology, which are costlier than senators. Further, different customisable automated machinery is available depending on the demand for the crops and the size of the field [54]. Additionally, the IoT systems are connected to a wireless system; a server and a database are essential for automated decision-making and precise application.

Therefore, most of the cost of an IoT system is allocated to databases and wireless systems. Additionally, there is the further cost of instances associated with IoT-based smart agriculture technology. The IoT systems are interconnected; hence, a fault in one system can cause the overall system to fail. Therefore, in such situations, the growth of the plants can be impacted.

6.3 High energy consumption of the system and environmental factors related to IoT devices impact the implication of IoT devices for smart agriculture: When analysing past literature, it was noted that IoT-based systems have a high energy consumption rate. Additionally, such factors impact the environment and increase emissions from the system. Moreover, environmental concerns and excessive energy consumption hinder the successful integration of IoT devices for smart agriculture [55]. IoT systems depend on many sensors, data processing devices, and wireless communication networks, adding to energy requirements. In off-grid or remote farming locations with constrained energy supplies, such high energy consumption of smart agriculture systems strains the power resources available. It raises the overall operating expenses [56]. Using low-power communication protocols, implementing energy-efficient designs, and maximising device utilisation can all assist in overcoming this obstacle.

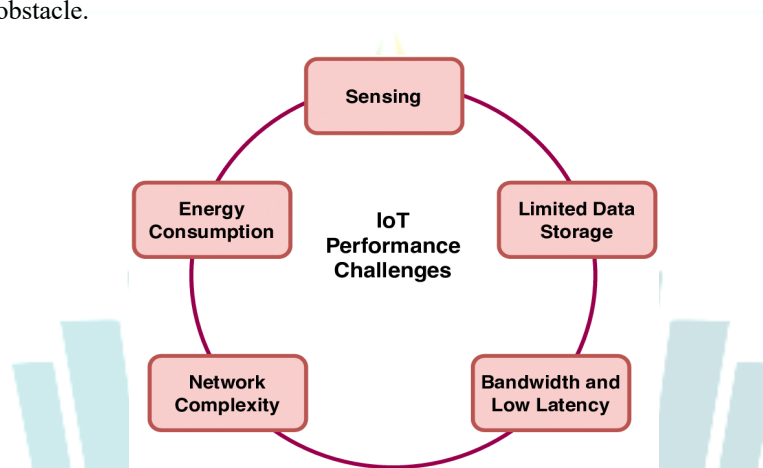


Fig.10. Challenges of implementing IoT systems in agriculture [19]

Moreover, it was noted that IoT devices are exposed to extreme weather conditions that impact the essential mechanical devices for the process. These external influences may affect the lifetime and functionality of IoT devices, resulting in malfunctions or decreased accuracy. Ruggedised designs, protective enclosures, and thoughtful positioning may increase device longevity.

Balance energy consumption and environmental factors to ensure the sustainable deployment of IoT devices in agriculture [57]. Furthermore, it was noted that the dependency on conventional power sources can be significant when using renewable energy innovations such as solar panels and kinetic energy converters. Durable gadget designs and materials that resist various conditions are essential for sustaining constant and dependable data gathering. Smart agriculture can maximise IoT advantages while reducing energy consumption and guaranteeing the durability of installed instruments.

6.4 The gap in the technical knowledge for the use of IoT technology for smart agriculture is an issue that hinders the implication of IoT-based systems in agriculture: At the time of reviewing past literature regarding smart agriculture using IoT Technology, it was noted that the knowledge gap is a significant issue. Moreover, the implication of IoT technology is a complex network of different elements; therefore, it can be contemplated that a certain amount of technical knowledge is associated with using such advanced technology for agriculture [58]. In addition, it was noted that the frequent users of agriculture technology are farmers who need to know how to use such delicate machinery. Additionally, the initial phase of modern technology can be the reason for such a knowledge gap [59]. Moreover, the knowledge gap can impact the efficiency and production of the crops.

In addition, from the review paper of the past analysis, it was noted that the knowledge gap hinders the identification of issues in the system. Therefore, such factors can impact the decision-making process [60]. Additionally, such a fault can lead to significant losses for farmers. Thus, the above-discussed issues of implementing IoT-based systems can be understood as specific. Additionally, it can be comprehended that along with the generalised use of the system, providing relatable training can benefit the users, and a smooth implication can be expected.

7. Results and recommendations

The review of past literature found that the implications of IoT-based systems are comparatively new and effective for smart farming [61]. At the same time, it was noted that specific components of smart agriculture and IoT technology form a symbiotic relationship. To work systematically for better yield, IoT-based systems need to be strategised. In addition, the implication must be according to the demand for the crops and the soil. It was noted that IoT can benefit smart agriculture with a systematic approach. Implementing different sensors and modules for the IoT-based system can be helpful for farmers [62]. Moreover, tasks such as irrigation and fertilisation of plants can be automated with the implication of IoT-based systems. At the same time, it was observed that some of the papers have emphasised the energy consumption of IoT systems for smart agriculture. It was observed that there were specific issues at the time of implementing the IoT technology for agriculture [63]. One of the significant issues noted is the farmers' knowledge gap. Moreover, the implication of different systems was reported to be a substantial issue for the implication of IoT-based systems [64]. Thus, to counter such problems, it is essential to counter with reliable skill training and observation methods.

At the same time, it was observed that energy consumption is a significant factor for agriculture's IoT-based systems. Moreover, IoT systems are comprised of various factors that consume considerable power [65]. Hence, such issues can be countered with the implication of green and renewable energy, such as solar and biogas power. The cost-effectiveness of the IoT-based system is one of the issues which needs to be countered with large-scale implications. Moreover, large-scale implications can improve the OI for the farmers and increase the benefits of IoT Systems for agriculture.

8. Conclusion

Thus, a review paper on the topic of smart agriculture using IoT systems is presented in the study. The study is conducted in a secondary qualitative manner and has referred to all the findings from past literature. Moreover, a systematic discussion of the factors related to smart agriculture is presented in the study. Additionally, different components of the IoT systems are coherently discussed to comprehend the topic better. From the discussion of facts, it was noted that past IoT-based systems aid in analysing soil quality and monitoring yield's nutrient value. Therefore, with the help of IoT-based systems, an improved crop yield is possible—additionally, IoT-based systems aid in automating processes such as irrigation and fertilisation. However, the knowledge gap related to IoT systems is a significant issue for the initial implication and scalability of smart agriculture using IoT systems.

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