



# A Comprehensive Study On The Implementation Of The Smart Farming Through The Utilization Of Iot In Agriculture

MS. Bhavika N Patel,

Lecturer,

Department of computer engineering,

CGPIT, UKA TARSADIA UNIVERSITY, BARDOLI, Gujarat

INDIA

*Abstract:* Food security is a pressing concern for countries worldwide, driven by factors such as a growing population, dwindling renewable resources, diminishing agricultural land, and unpredictable weather patterns. To address these challenges, the agricultural sector is embracing "smart agriculture," which leverages the Internet of Things (IoT) and artificial intelligence (AI) to optimize operations and boost production. This approach integrates a range of innovative technologies and techniques, including large volumes of data, sensing technology, networking, cloud computing, and end-user apps. The aim of this study is to analyse current advancements in smart applications that utilize IoT and AI technology in smart agriculture. It also examines the challenges and obstacles associated with these applications, as well as the trends and future prospects in the field. This research will help determine how IoT and AI applications can be integrated into the smart agriculture industry. The findings of this study will provide valuable information for future research and development of IoT and AI solutions to enhance the quality and profitability of the agriculture industry. The implementation of smart application techniques can offer rapid, safe, and large-scale classification with benefits such as immediate data availability, adaptability, ease of use, and precise spatial resolution to increase production while minimizing energy and time requirements.

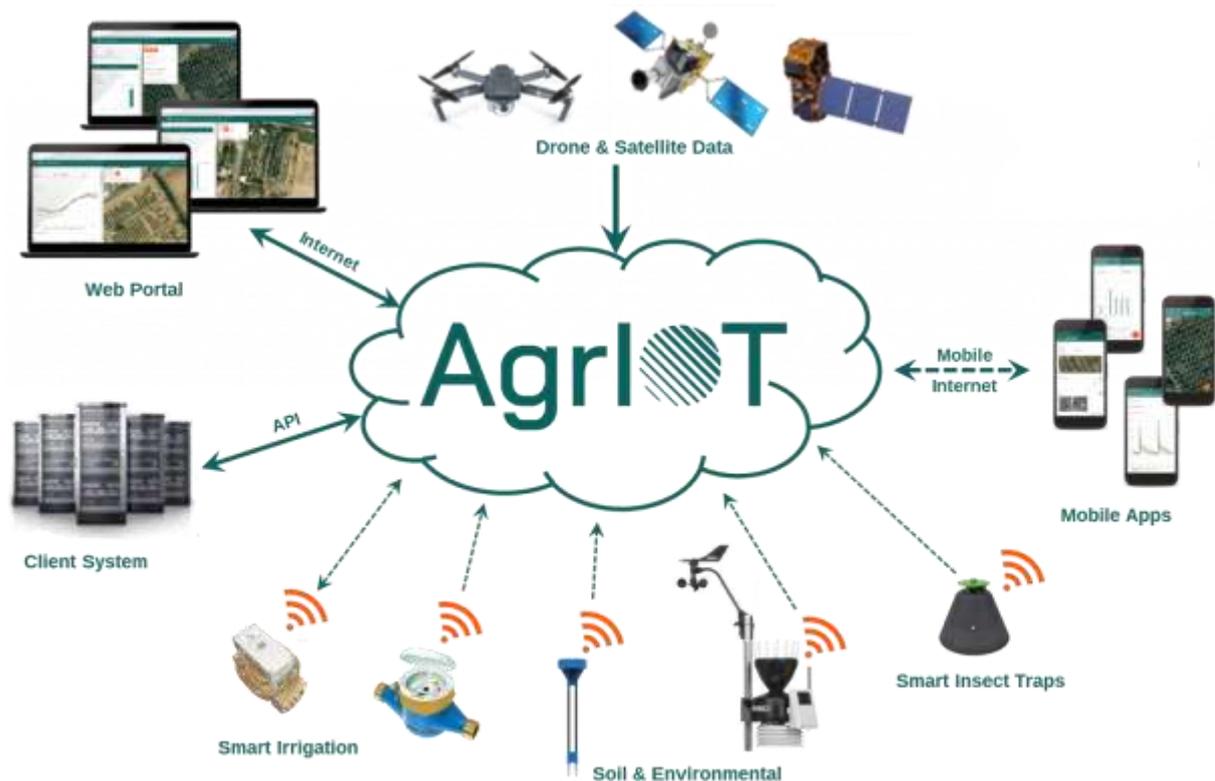
***Index Terms* – Automation, Internet of Things, Smart agriculture**

## I. INTRODUCTION

The primary objective of this paper is to examine the application of an Internet of Things (IoT)-driven system in the precision agriculture field. Every year, farmers confront substantial losses due to insect invasions and inadequate equipment to manage their farms efficiently. This chosen article provides an outline of the recommended systematic equipment and approach for implementing IoT in smart farming.

This review highlights an updated technology for agricultural smart management by revising every area, such as crop field data and application utilization. Agricultural crop production and its management is a challenging task due to variations in environmental factors, soil factors, and water quality-related parameters worldwide. Due to the increasing population and changing environmental scenario day by day, high agricultural production per unit hectare is required globally ([19]). The phenomenon of climate change is a result of the environmental stress caused by an expanding population and numerous industries, especially agriculture. Several human acts lead to land deterioration, affecting crop quality, chemical pollution causes dead zone conditions and end-dangers marine life. Thus, the use of the smart application in agriculture may be crucial in offering viable solutions to significant problems like disease and pest infestations, insufficient biological application, incorrect water application and elimination, weed management, and yield forecasting ([22]; [25]; [70]). Crop protection activities against climate change, soil

nutrients, land suitability, cultivation practices, method of cultivation, artificial nutrients applications, water management, etc. can enhance the production yield. Although the use of agrochemicals can efficiently boost crop yield and quality, it has also increased environmental challenges in recent years. Overdose of pesticides/fertilizers or poor spraying equipment during chemical plant protection operations can have major consequences for human health and the environment. In the case of developing countries with densely crowded areas, when enlarging land space for agriculture and crop protection practices is difficult, the only option is to become smarter in the technology used in agriculture through the use of cutting-edge technologies such as the Internet of Things (IoT) and Artificial Intelligence (AI). They have already started capitalizing across all industries including agriculture. Artificial intelligence (AI) is “the science and engineering of making intelligent machines, brilliant computer programs,” according to Professor McCarthy. For many years, basic artificial intelligence has been provided by governed programs that exhibit a fundamental kind of “intelligence” under particular conditions ([35]; [22]).



**Fig. 1.** IoT applications in the field of agriculture for smart farming.

Advancements in these digital technologies have made revolutionary changes in agriculture by providing smart systems that can monitor, control, and visualize various farm operations in real-time and with comparable intelligence to human experts ([41]). Better insights may be produced from data obtained in the field by using digital technologies such as AI and IoT-based applications, allowing farming techniques to be planned efficiently with minimum manual work. These technologies reduce the risk of managing the field during bad weather conditions and also provide profit to farmers during a shortage of labour. IoT has been used in several areas recently, including institutional management practices ([42]), medical ([44]), home automation ([38]; [31]), smart cities, energy optimization, self-driving automobiles, intelligent farming and transportation. Fig. 1 presents an extensive and diversified example of IoT applications in the field of agriculture for smart farming.

Many research studies focus on various smart applications in the agriculture sector, whereas at present, farmers are unaware of these re-cent technologies and practices. The basic knowledge of adopting an appropriate smart technology and its applications with working conditions for sustainable production is still not very clear. However, it is necessary to provide systematic information on the advantages and uses of various methods in smart farming with proper understanding to get the maximum benefit from an economic and management perspective. The present study identifies and extracts meaningful information about smart technologies and other mobile applications, i.e., chatbot systems utilized for smart farming.

Keeping in mind the above-mentioned facts, the major objectives of this paper are:

- To examine current developments in smart applications using IoT and AI technology for agriculture.
- To highlight issues and challenges particularly related to networking and open-source programs for smart agriculture
- To evaluate the agricultural development from the ancient age to the present era.
- To draw attention to the trends and prospects in smart agriculture.

### **Paper representation**

#### Section :2

This paper is organized as follows presents smart farming towards Agriculture 4.0 and 5.0 and the smart applications utilized in farming practices, including many subtopics such as automatic irrigation practices, automated vehicles, drone applications in agriculture, harvesting, sowing, weeding, and crop maintenance.

#### section: 3

various methods of smart farming, including the Internet of Things (IoT), artificial intelligence (AI), and blockchain technology used in smart agriculture. Also, this section discusses sensor technology, its types, and mobile applications, including chatbot systems used in smart agriculture.

#### Section:4

Also, a detailed summary of the advantages of IoT technology in the agriculture sector is discussed.

#### Section:5

highlights future research directions and examines some of the challenges that emerging innovations in the agriculture sector are facing.

#### Section 6

discusses the conclusion of this paper, including the authors' perspectives on the subject of the study and potential directions for further research.

List of Agriculture Revolutions in India From 1960 to 2023

SRNO	NAME	Main Objective
1	Green Revolution	Food Grains Production
2	White Revolution	Milk Production
3	Blue Revolution	Fish Production
4	Yellow Revolution	Oilseed Production, Mustard & Sunflower

### **Smart farming: agriculture 4.0**

To meet the worldwide challenge during the twenty-first century, a major agricultural revolution is required, one that will allow technology to increase productivity while ensuring sustainability in the environment. The term "Agriculture 4.0" refers to the fourth agricultural revolution, which makes use of digital technology and aims to transform the industry into one that is more environmentally conscious, intelligent, and productive ([28]). With the application of Agriculture 4.0 technology, farmers may cultivate their land more methodically and accurately predict the results. The practice of effective precision farming requires the use of Agriculture 4.0 technology to achieve its maximum potential. The infrastructure for connected farming must be based on real-time data and cover a large area, based on the requirements of the agricultural operation and the goal of IoT implementation ([28]).

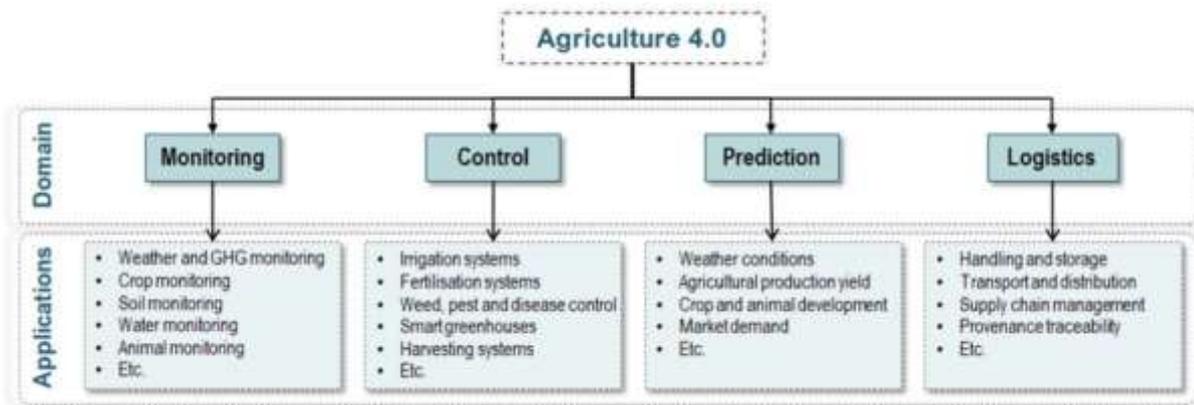


Fig. 2. The agriculture 4.0 application sector distributions.

The necessity for agricultural systems to balance the environments that support our way of life with the production of sufficient quantities of wholesome, reasonably priced food is a significant challenge faced by civilization today. The agriculture 4.0 application sector distributions are presented in Fig. 2.

Agriculture 4.0 has four pillars, i.e., advancement, modern equipment used, scale-up data for supervision, and environmental sustain-ability for fruitful farming.

Agri-culture 4.0 and its evolution as Agriculture 5.0 are resource-effective approaches to developing more advanced technologies in the agricultural environment. According to the theory of “Agriculture 5.0,” fields employ machinery that enables self-governing choices and unmanned operations using precision farming techniques. Therefore, the usage of robotics alongside a certain type of AI is implied by Agriculture 5.0. The evolution of agriculture from the ancient age to the modern era is shown in Fig. 3.

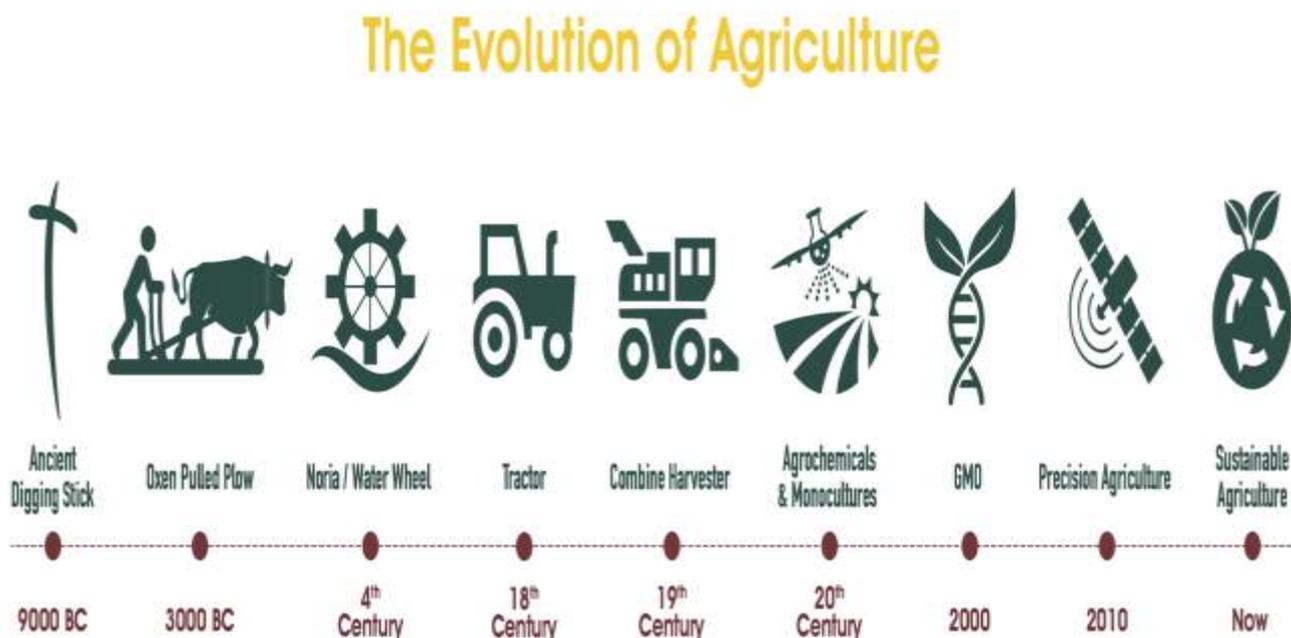


Fig. 3 The evolution of agriculture from the ancient age to the modern era

The growth of Agriculture 5.0 demands the establishment of techno-logical standards to ensure equipment compatibility. Since agricultural machinery lasts a long time, precautions are taken to guarantee that any technological advancement is supported by manufacturers and other sectors of the economy and remains compatible with updated machinery. The agriculture industry has seen substantial technological advances over the past few decades. Modern technology is converting conventional agricultural concepts into smart agriculture.

Indian farmers have currently started employing a method of farming known as “smart agriculture,” which is a combination of several smart technologies. The integration of wireless sensor networks for remote surveillance by technologies such as IoT enables a wide range of applications to provide their output more rapidly and precisely. India and other developing nations are in a position to quickly produce food supplies by implementing innovative technology.

Farmers may regulate the timing and amount of water that they produce by using smart irrigation application technology. The intricate IoT sensors have the potential to enable the cultivation framework to function autonomously, utilizing data from field-based sensors to adjust the water system ([6]). Among the many benefits of automated or con-trolled irrigation are increased accuracy, more economical utilization of water, and a decrease in human error.

Farmers may gather and examine data in a smart agriculture system to fertilize and care for their crops. The smart agricultural system offers more precise and cost-effective methods for forecasting and safeguarding crop growth. By raising earnings, decreasing waste, enhancing efficiency, and becoming environmentally friendly, the agricultural business is becoming more digitalized by integrating various technologies. By assessing water quality and minimizing water waste, information technology-based smart farming practices may assist farmers in managing their water resources.

Farmers employ farm tractors for a variety of agricultural tasks. With time and advances (such as cameras and machine vision frameworks, GPS, IoT, and LiDAR), self-operated vehicles get more skilled and autonomous. These advancements ultimately reduce the need for human intervention to operate these devices efficiently ([24]). The probability of disaster is increased by the change in the environmental condition and its undefined nature. Thus, the intrinsic safety and dependability are essential factors in the operation of machinery used in field activities. Agricultural automation systems include the automation of equipment used in farms, intelligent irrigation processes, protected cultivation monitoring, farmstead management, dairy farm management, harvesting and threshing operations, storage structures, and transportation. Autonomous agricultural vehicles (AAVs) have become more and more significant in recent years, mostly because of advancements in the field of self-driving automobiles in the transportation sector ([30]).

### **Drone applications in agriculture**

Drones have been utilized commercially for agricultural purposes since the beginning of the eighteenth century, but their use has grown significantly as a result of the expansion of the Internet of Things and advancements in communication technologies. It may carry out a variety of tasks that enhance farming methods ([33]). Drone activities include, but are not limited to, water supply, soil testing, grafting, sprayers, crop assessment and its assessment, crop illness, overall plant wellness measurements, insecticide, fertilizer, canopy cover, fore-casting and counting of plants, crop height measuring, etc., which can all be monitored by drones outfitted with multiple sensors, cameras, thermal, multi-spectral, and optical imaging cameras ([26]; [24]). Ethe-real photographs may be produced quickly by using robots that have cameras installed. Farmers may utilize these images to cultivate their land and improve every aspect of their holding. Due to their great capabilities, agricultural unmanned aerial vehicles (UAVs) are now being used in numerous aspects of agriculture, including seed dropping, planting, growth evaluation, mapping, fertilizer, and pesticide applications. As a result, it is anticipated that the market for agricultural UAVs and associated innovations will continue to expand ([29]).

### **Harvesting**

The farmer can concentrate on additional duties owing to the sophisticated techniques, IoT devices, and mechanized machinery. With the help of an IoT framework, these machines can continuously monitor fields, monitor crops using their sensors, and collect appropriate harvests as needed at the right time. The process of capturing energy from different external sources and turning it into electrical power is known as energy harvesting. The lifespan of sensors can be achieved through the application of energy harvest technology, which also occasionally eliminates the need for batteries. Furthermore, harvesting energy provides practical and financial benefits by optimizing energy consumption and lowering network maintenance expenses ([37]). In certain situations, like rural areas or remote locations, the deployment of wireless sensor networks is advantageous.

### **Internet of Things for agriculture**

The Internet of Things (IoT) is an emerging technology that makes it possible to create a system that supports agricultural processes ([25]; [34]; [17]). An Internet of Things (IoT) system comprises several components that enable it to perform different functions, including sensing, identification, actuation, communication, and management systems. Fig. 4 represents the IoT structure.

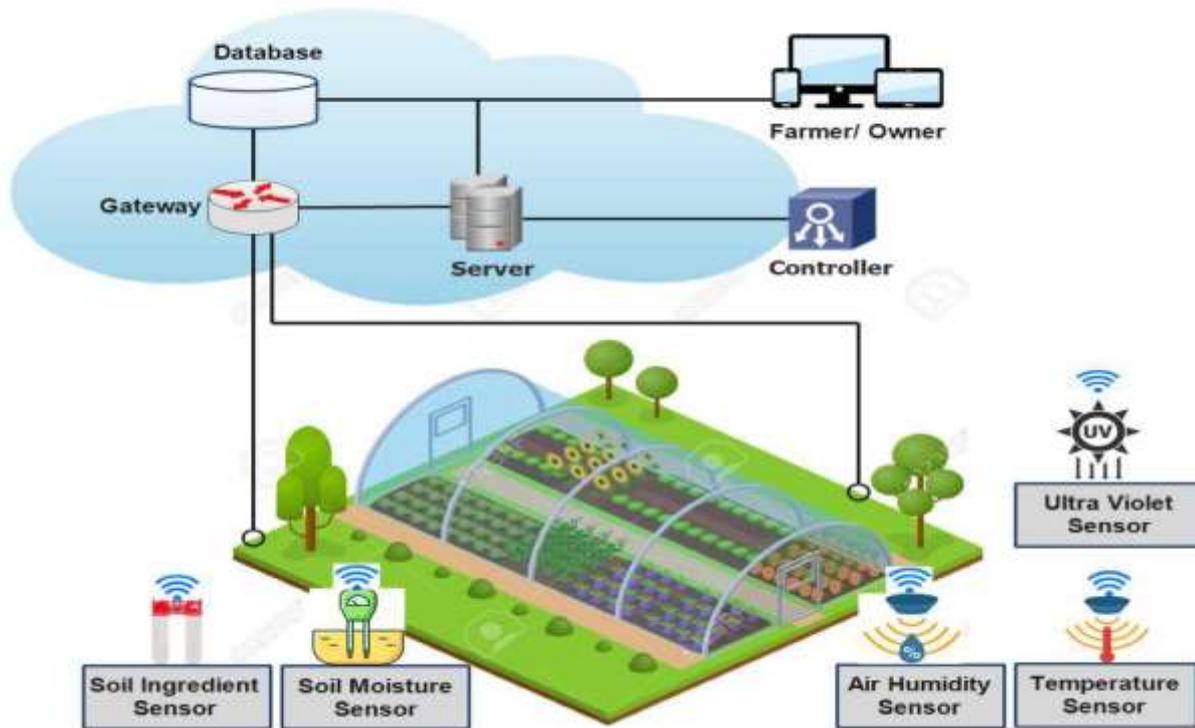


Fig.4 Structure of IoT.

The IoT system applies to various applications of agriculture, such as crop protection and management, farm monitoring, remote monitoring systems, decision support tools, automated irrigation systems, frost protection systems, fertilization systems, temperature and humidity monitoring, rainfall observation, fertilizer effectiveness, animal tracking, storehouse monitoring, water tank dimensions monitoring, theft detection, equipment tracking, and monitoring remotely ([34]). A decrease in the number of electronic incidents involving agricultural producers and IoT technology has made it simpler to obtain data related to agriculture. With better input and process optimization, fewer resources, and more environmentally friendly agricultural practices made possible by these future technologies, productivity may be increased. The agricultural sector's utility would be improved by the combined use of IoT technology with data analytics and wireless sensor networks (WSN), resulting in improved crop output and operational scheduling ([34]). The WSN collects data from a variety of smart sensors and transmits it to a centralized server using different communication methods. The factors that can decrease crop yield include pest attacks, excessive use of pesticides, wild animal and bird attacks, unpredictable monsoon patterns, insufficient water, improper water use, and inadequate knowledge of agricultural practices. In the agricultural industry, various criteria must be evaluated depending on the specific area being considered, such as crop monitoring, forestry monitoring, livestock farm monitoring, weather monitoring, micro-climate modification, aquaculture management, and logistics management.

#### Sensor technology for smart agriculture

Smart farming depends significantly on the use of sensors. Farmers may maximize crop productivity by adjusting their surroundings with the help of sensors. In essence, weather stations, robots, and drones may all have sensors mounted to them. Farmers may learn a lot about vegetation and the environment from the information the sensors tell them. Food 4.0 emphasizes the extensive use of sensor technologies as part of the precision agriculture concept. Using scarce resources like water, fertilizer, and seedlings, farmers may boost agricultural productivity with the use of sensors. Mobile applications can be used to operate the sensors and camera. Since optical sensors are capable of scanning an entire area and acquiring the required images, they are typically mounted on drones or robotic machines ([33]). Additionally, these smart sensors help to improve crop yield, livestock tracking, soil moisture monitoring, remote water tank level monitoring, temperature and humidity sensing, the security of farmland, monitoring environmental conditions, and equipment tracking ([34]). These sensors include, for example, temperature sensors that sense temperature, soil moisture sensors that measure.

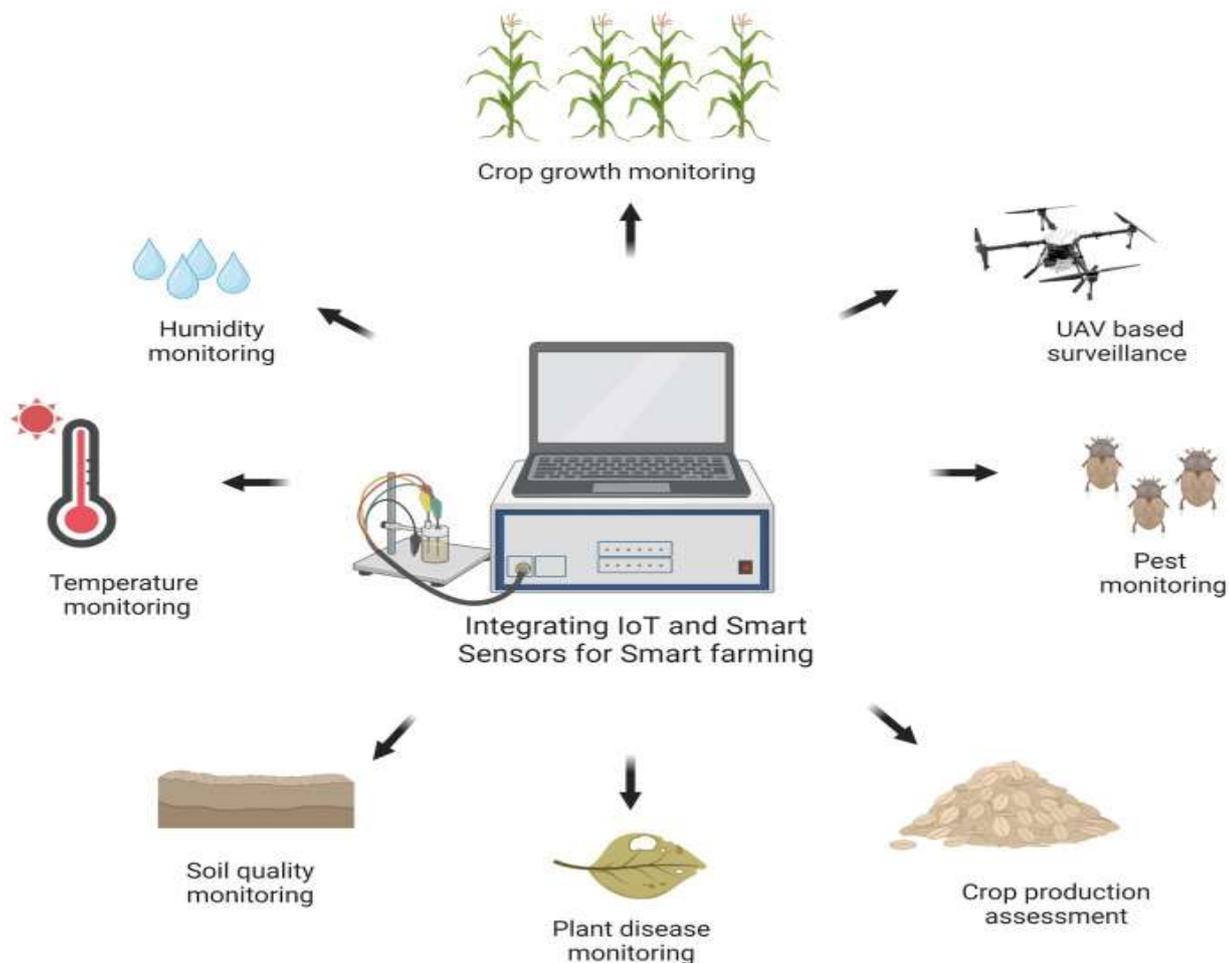


Fig. 5. Types of smart sensors used in agriculture

SR.NO	Types of sensors	Working principle	Usage	Reference
1	Electromagnetic Sensor	Uses electrical circuits to monitor electrical impulse conduction or buildup in soil	Measure the concentrations of organic matter and residual nitrate in the soil, record electromagnetic reactions, and track the rate of transpiration in real time.	[1];[2]
2	Acoustic-based sensors	monitor changes in the noise intensity in fields of agriculture	Identifying and keeping an eye on the population of pests; collecting fruit; and following the growth of aquatic plants	[3]
3	Optical sensors	Variations in light reflectance are evaluated	Utilized for identifying many properties of soil, such as moisture content, mineral content, soil texture, and soil colour. Fruit maturity is detected by optical sensors mediated by fluorescence. Orchard canopies are monitored using microwave scattering in conjunction with integral optical sensors.	[4]

4	Ultrasonic ranging sensors	Uses an ultrasonic sensor to identify an object's proximity by sending and receiving ultrasonic pulses.	Aids in weed identification, agricultural canopy monitoring, and insect detection.	[5]
5	Mass flow sensors	Sensors track the mass movement of grains using several modules, including an internal system, data storage, and a moisture content sensor.	Measure the grain flow via a combined harvester to aid in yield production assessment.	[6]
6	Electrochemical sensors	Separate sensors capturing soil electrochemical gradients in agriculture	Assists in measuring the pH and nutritional content of the soil and also for precision agriculture	[7]
7	Light detection and ranging (LIDAR)	Light Detection and Ranging (LIDAR) optical sensors work by varying the characteristics of optical signals in response to variations in a measurement.	Services related to agricultural land, including 3D modeling, tracking soil erosion, mapping agricultural land, and identifying different types of soil.	[8]
8	FPGA (Field programmable gate array) based sensors	Uses digital circuits to wrap logic blocks and silicon-based processors.	Measures the rate of plant transpiration, moisture content, humidity, and irrigation	[9]
9	Eddy covariance-based sensors	Constant measurements throughout huge agricultural fields.	Track variations in the concentrations of different gases in agricultural areas, such as methane, CO <sub>2</sub> , and water vapor, among other greenhouse gases	[10]
10	Battery-free and self-powered sensors	Solar cells are used to power sensors.	Assist in detecting environmental elements like humidity and temperature, among others. Also used to keep an eye on food products' quality.	[11]
11	Airflow sensors	It uses distinctive identifying traits to sense many soil properties.	Examine the soil's permeability, air content, moisture content, and if it is in a mobile or stationary state.	[12];[13]
12	Flexible and wearable sensors	Flexible materials are used to create sensors that can be attached to various plant components.	Facilitates the sensation of temperature as well as the form, size, and growth of various plant components and plant protection.	[14]
13	Mechanical sensors	Sensors take measurements of the force determined by strain gauges or load cells.	Computes the compaction of soil particles and the soil's mechanical resistance.	[15]

### **Advantages of IoT technology in the agriculture sector**

IoT technology has several benefits for the agricultural industry ([34]). A few advantages are listed in the section that follows:

1. **Collective Information:** IoT technology, particularly in rural and isolated locations, can support the growth of cooperative farming. The development of applications that allow sharing, shared farm data management, and enhanced interaction between farmers and agriculture professionals can be facilitated by IoT.
2. **Safety and Security:** The challenges of ranchers extend beyond the need to produce more food; they also include ensuring reliability, protection, and availability of high-quality food. There have been several reports of problems with the standard of food being supplied to the market, including food adulteration, counterfeiting, artificial plant augmentation, and large fruit sizes. These problems are mostly affecting medical conditions and may have detrimental effects on economic growth.
3. **Competitive and Challenging Nature:** Agriculture is becoming a more competitive industry due to the growing demand for increased agricultural output and the application of innovative technology. It strengthens a structure where information exchange in farming sectors using IoT technology will offer additional potential for management, marketing, and monitoring.
4. **Growth and Development: Development and Spread of Prosperity:** The usage of IoT technology may provide fresh perspectives on job creation. Farmers stand to gain from this approach as it eliminates the need for “intermediate men,” who are often misused and may engage directly with clients, yielding greater returns.
5. **Minimal expenses and damages:** The only advantage of IoT technology is that it's able to identify instruments and devices that are located remotely. Farmers have more decision-making power because of IoT technology, which informs them of the best times to apply insecticides and herbicides. They might be able to lower their agricultural expenses and crop devastation thanks to this.
6. **Awareness:** The network of IoT devices can regulate access to WSNs in farming industries and operate economical services. Smartphone apps provide information about goods, services, prices, and market analysis. Additionally, a variety of regulations, laws, and government initiatives on different agricultural farm produce.
7. **Resource Management:** IoT technology will enable immediate monitoring and sensing of agricultural capital, safeguarding various equipment against theft, updating components, and enabling the timely completion of jobs.

### **ACKNOWLEDGMENT**

With increasing population growth worldwide, global warming, and a lack of resources at present, agriculture is severely challenged to fulfil the demand for high-quality and quantity food. The present study demonstrated how crucial smart farming is to raising and enhancing agricultural productivity to help reduce the gap between supply and demand for food. The adaptation of smart technologies like IoT and AI demonstrates enormous promises for many different aspects of farming. IoT is regarded as the foundation of smart agricultural technology since it links every part of smart systems, including those used in other applications than agriculture. The insights acquired from profitable companies might assist researchers in devising novel approaches and remedies for modern farming practices. This paper offers a summary of how smart technology will transform the agriculture industry, assisting farmers in better managing their properties while also generating more income. Furthermore, this study facilitates the identification and investigation of the evolutionary trends in Agriculture 4.0 and Agriculture 5.0. In addition, this study will provide systematic information on the advantages and uses of various methods in smart farming and provide a proper understanding of how to get the maximum benefit from an economic and management point of view. In the agricultural sector, the evolution of agriculture from traditional to modern practices with Agriculture 4.0 and 5.0 is an irreversible trend that cannot be stopped. These technologies might link people's modern connectedness using their cell phones. Due to their low cost and ease of use, smart-phones, the IoT, and AI have all contributed to the gradual development of the integration of communication and information technologies into the psycho-social structures of people, cities, and industries. This integration offers tremendous potential for discovery and exploitation. It can be concluded that smart agriculture farming will fulfil the demands of an extensive and adaptable agricultural system that protects the environment and sustainability and demonstrates flexibility regard-less of upcoming challenges to provide a steady and long-lasting source of income within constrained limits. Additionally, by 2050, IoT and AI technologies will assist farmers and the agricultural industry in meeting the need for food.

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