SMART AGRICULTURE WITH INTERNET OF THINGS AND UNMANNED AERIAL VEHICLES

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Abstract

Unmanned aerial vehicles (UAVs) and the Internet of Things (IoT) are two popular technologies used in agricultural sectors that are transforming conventional farming techniques into a new era of precision agriculture. In this work, we conduct a review of recent studies on the use of IoT and UAV technologies in agriculture. We go through the fundamental ideas behind IoT technologies, networks, and protocols used in agriculture, as well as IoT solutions and applications for smart farming. The IoT is an innovative technology that offers practical and dependable answers for the modernization of several fields. Solutions built on the Internet of Things are being created to autonomously manage and monitor agricultural fields with the least amount of human participation. The article covers a wide range of technological elements related to IoT in agriculture. The key elements of IoT-based smart farming are explained. The field of IoT agriculture has certain open research issues have been mentioned.

Keywords: Internet of Things (IoT), Smart Farming, Applications, Unmanned Aerial Vehicle(UAV), Wireless Sensor Network(WSN), Agriculture.

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1. Introduction

Auto-ID Center at MIT and its pertinent market research articles helped popularize the idea of IoT in 1999. IoT, in its simplest form, is the integration of several devices that use the embedded technology it contains to communicate, perceive, and react to both their internal and external conditions [1]. The IoT has emerged as the next-generation technology megatrend that has the potential to affect every sector of business thanks to its extended advantages of advanced connectivity of end devices, systems, and services. IoT offers suitable solutions for numerous uses, including

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smart agriculture, smart cities, security, retail, and traffic congestion industrial control [2]. IoT technology has been extensively studied in the agriculture sector to provide smart farming solutions [3]. By looking at many difficulties and obstacles in farming, IoT has brought about a significant shift in the agricultural environment [4]. Nowadays, with the development of technology, it is anticipated that agriculturalists and technologists would use IoT to solve challenges that farmers face, such as water shortages, concerns with cost control, and productivity problems [5]. Modern IoT technologies have identified all of these problems and offer fixes that will raise productivity while decreasing costs. We can gather data from sensing devices and deliver it to the main servers thanks to efforts done on wireless sensor networks[6]. Sensor data provides information on various environmental conditions, enabling accurate system monitoring. There are many more elements that affect agricultural production in addition to monitoring the environment or crop productivity, which is a consideration in crop evaluation. Additionally, IoT offers a well-organized scheduling system for constrained resources, ensuring that the optimum use of IoT increases productivity.

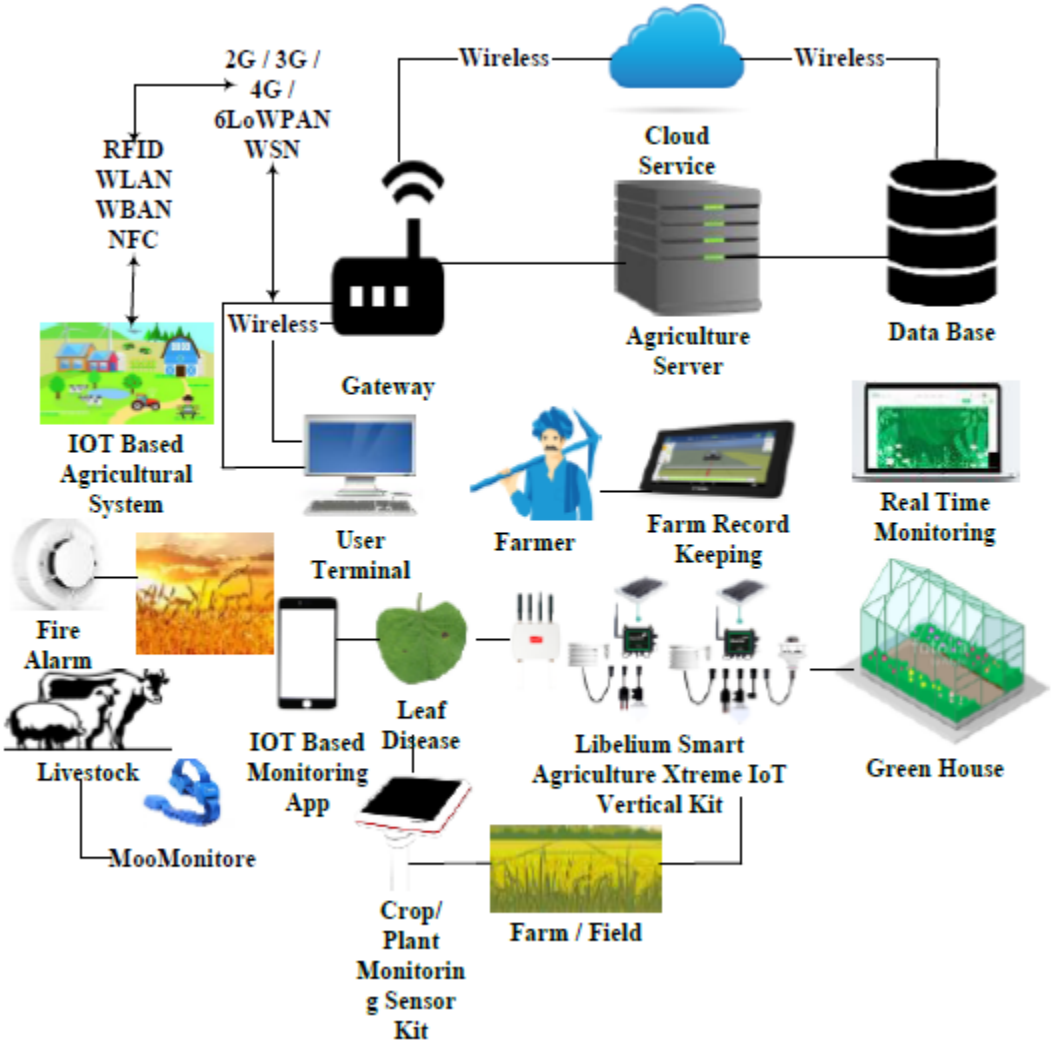

Figure 1. An overview of the agricultural trends

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By incorporating Information and Communications Technologies (ICT) with conventional agricultural methods, agriculture has just undergone a fourth revolution. Technologies that have the potential to revolutionize agricultural methods include remote sensing, the IoT, UAVs, big data analytics (BDA), and machine learning (ML). A wide range of agricultural parameters, including environmental factors, growth status, soil status, irrigation water, pest and fertilizer management, weed control, and greenhouse production environment, can be monitored in smart farming to increase crop yields, cut costs, and optimize process inputs. Since smart farming has a smaller ecological impact than traditional farming, it is a green technology strategy. With precision agriculture, leaching issues, emissions, and the use of fertilizers and pesticides sparingly on agricultural crops, it is possible to further minimize these issues as well as the effects of climate change. IoT is one of the most innovative wireless communication technologies available today [7-11]. The fundamental idea is the interaction between various physical entities or objects linked to the Internet utilizing certain addressing systems. IoT technology may be used in a number of vertical areas, including agriculture, industry, transportation, healthcare, and cars [12]. IoT devices offer helpful data on a variety of physical characteristics in an agricultural setting to improve farming techniques [13]. Since the great majority of IoT applications across multiple sectors rely on wireless data transmission, WSNs play a crucial role in IoT technology.

2. Literature Survey

Modern unmanned vehicles may be used in a variety of ways, including on the ground and in the air, manually operated, partially and fully autonomous, small and big. They may, in general, be modified to any form factor based on the situation and task. The airborne variants of UAVs offer the most adaptable answer because to their speed, mobility, and lack of reliance on traffic and roads. The most recent developments in electronics now make it possible to add ever-increasing processing power to the UAV, which frees up processing power from ground stations while lowering bandwidth requirements [14]. This allows for the development of more intelligent UAV that employ Machine-to-Machine principles to directly communicate with various devices and with one another to determine the best way to complete the task.

A brand-new WSN-based farm monitoring system was created by H. Chang et al. A precision agricultural monitoring strategy that offers farmers useful services was presented by Y. Jiber et al. It discusses the benefit of using precision agriculture to guide important decisions that might boost the production of the land while also maximizing the usage of various resources. A UAV-based architecture is described by F. G. Costa et al. [15] and may be used to build a control loop for agricultural applications where UAVs are in charge of spraying crucial chemicals on crops. The WSN installed on the agricultural field provides feedback that is used to regulate the chemical application procedure. A networked embedded greenhouse monitoring and control system based on straightforward embedded web servers and linking sensors and actuators through 1-wire protocol is described by Stipanicev et al. [16]. A WSN-based approach was put up by M. Martinelli et al. [17] for use in precision farming. A distributed WSN was used by Y. Kim et al. [18] to construct a remote sensing and control irrigation system. With the suggested system, low-cost Bluetooth wireless radio receivers were used to interface

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communication signals from the sensor network and irrigation controller to the base station.

In order to provide stable remote access to field conditions as well as real-time control and monitoring of the variable-rate irrigation controller, graphical user interface (GUI) software has been created. A. Hanggoro et al. [19] conceived and created a full system for monitoring and managing the humidity within a greenhouse. It utilizes an Android Smartphone that is Wi-Fi connected to a central server, which is coupled to a microcontroller and humidity sensor through serial connection. A large-scale greenhouse remote monitoring and control system based on GSM-SMS was created by S. Jin et al. [20]. The design and development of a prototype system that combines several current technologies for home monitoring and control and is compatible with the idea of a future "smart house" are covered by S. O. Al Mehairi et al. in their article from [21]. The numerous home appliances in this work are wirelessly connected through the Bluetooth standard to a home server and may be seen and operated from a mobile device using a portable MIDlet application. Using a WSN and GPRS module, J. Gutiérrez et al. [22] created an automated watering system. The programme used multiple threshold values to regulate various parameters. In contrast to previous studies in the field, in this study we suggest a mobile wireless robot that gathers data from various types of sensors and transmits it wirelessly to a central server. The information about various environmental elements around the plants is provided by the data gathered from numerous sensors on board the mobile robot, which in turn helps to monitor the entire agricultural area. Monitoring by itself is insufficient to increase agricultural productivity; a comprehensive solution is required.

3. Technologies in IoT Agricultural

Since there are many different technologies utilized in IoT agricultural solutions, it is difficult to list them all explicitly. As a result, our discussion has concentrated on a few key technologies that have been essential to the modernization of IoT agricultural services.

Communication Networks and Protocols : IoT networks for agriculture include a variety of long- and short-range communication networks. Designing sensors and devices for crop or field monitoring is made easier by a number of IoT networks technologies [7]. The foundation of IoT agricultural network systems and applications is communication protocols. All agricultural data and information are exchanged using them through the internet.

Big Data Analytics and ML : Big data is made up of a lot of useful information produced by agricultural sensors. Big data analysis offers several, effective crop monitoring techniques at various stages . Big data analysis in agriculture has been the subject of an excellent literature review [23]. The reason neural networks are so well-known is that they deliver the best solutions quickly. Utilizing cutting-edge neural network concepts and technology, intrusion detection has been made possible. However, the detecting module and tracking that neural networks offer are their most crucial features. An IoT-based hydroponic system has been created utilizing deep neural networks.

Cloud computing (CC) and Edge Computing (EC): IoT and cloud computing working together in agriculture gives everyone access to common resources. Cloud computing plays a crucial role in executing activities and meeting diverse agricultural demands upon request through the network. It has been suggested to use cloud-based software architecture to process and retrieve data and perform agricultural operations more accurately. Edge computing is viewed as a way to simplify data processing at the point of data production, which is typically

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embedded devices like sensors, actuators, and many more. The core of cloud computing is considered to be edge computing or fog computing. The characteristics and specifications of smart farming are taken into account while deploying this technology.

Robotics : For the objective of smart farming, several agribots have been developed that reduce the number of farmers by accelerating labour using cutting-edge methods. Simple tasks like weeding, spraying, and seeding are carried out by agribots. IoT is used to operate all of these robots, enhancing crop output and resource usage. A multisensor robots technique has been suggested for ground mapping and characterization.

4. Wireless Sensor Networks (WSNs) in Agriculture

A WSN is a collection of geographically and purposefully placed sensors that monitor environmental physical conditions, temporarily store the information they obtain, and communicate that data to a central point. The majority of researchers are now interested in an effective WSN created for smart farming. A WSN for smart farming consists of multiple nodes. Sensors, microcontrollers, converters, and power sources are all components of a sensor node[24-26]. One or more sensors can be supported by a node to track and measure various factors. Numerous soil-related physical properties, including soil moisture content, soil water content, soil temperature, soil electrical conductivity, and weather-related factors must be measured for agricultural uses. Nowadays WSNs are capable of self-organization, self-configuration, and self-diagnosis. WSNs are created and installed to solve issues or support applications that can't be supported by conventional technology. The significant decrease and simplicity of wiring, which results in a more streamlined end system, is the most evident benefit of WSNs. Monitoring techniques are made possible by wireless sensors in risky, unwired, or distant locations. With the help of this technology, sensors can be installed with virtually infinite flexibility, and networks are more resilient. Furthermore, wireless technology lowers installation costs and streamlines network maintenance. The mobility of wireless sensors is one of their main benefits. These sensors can be mounted on farm equipment, such as tractors, or on livestock. Farmers are able to watch the entire field and measure important characteristics as a consequence. A simple WSN node arrangement is shown on Fig. 2.

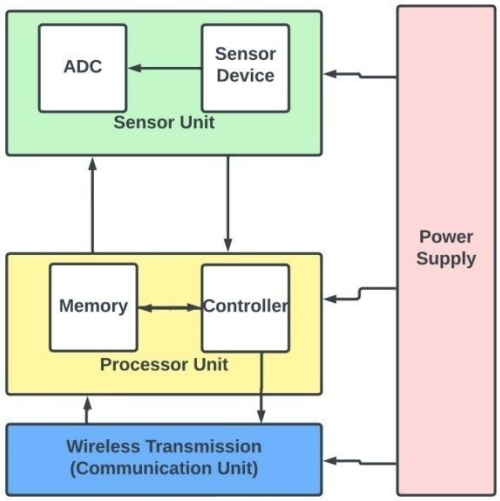

Figure 2. A simple WSN node architecture

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5. Applications of IoT in Smart Farming

A modern, efficient method of farming and food production known as "smart farming" uses sustainable practices. It is an application of integrating cutting-edge technologies and linked devices into agriculture. IoT is a key component of smart farming, which eliminates the need for farmers and producers to perform physical labour while simultaneously enhancing production in every way. The IoT has provided enormous benefits, including effective water usage, input optimization, and many others, in light of the dependence of modern agricultural developments on agriculture. The significant advantages, which have recently changed agriculture, were what made a difference.

Figure 3. Applications of Iot in agriculture

Climate Conditions: A poor understanding of climate has a significant negative impact on crop output, both in terms of quantity and quality. Climate is particularly important for farming. You can learn about the current weather conditions thanks to IoT technologies. The agricultural fields have sensors installed both inside and outside of them. They gather environmental information that is utilized to choose the best crops for the specific climatic circumstances. The whole IoT ecosystem is made up of sensors that are highly accurate in detecting real-time meteorological variables like humidity, rainfall, temperature, and more. Numerous sensors are available to detect each of these factors and may be set up to meet your needs for smart farming. These sensors keep an eye on the crops' health and the surrounding weather.

Precision Farming: One of the most well-known uses of IoT in agriculture is precision agriculture/farming. By using smart farming applications including animal monitoring, vehicle tracking, field observation, and inventory monitoring, it improves the agricultural practice's precision and control.

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Precision farming aims to assess data produced by sensors and respond appropriately. With the use of sensors, precision farming enables farmers to collect data, evaluate it, and make rapid, informed decisions. Numerous precision agricultural methods, including livestock management, vehicle monitoring, and irrigation management, all contribute significantly to raising productivity and effectiveness. You may assess soil conditions and other relevant characteristics with the use of precision farming to improve operational effectiveness.

Smart Greenhouse: IoT has made it possible for weather stations to automatically change the environment conditions in accordance with a specific set of instructions, making our greenhouses smarter. The usage of IoT in greenhouses has removed the need for human interaction, which reduces costs and boosts accuracy throughout the process. For instance, creating contemporary, affordable greenhouses utilizing IoT sensors driven by solar energy. These sensors gather and send real-time data that is used to precisely track the status of the greenhouse in real-time. The sensors allow for the monitoring of greenhouse conditions and water use via emails or SMS warnings. IoT is utilized for automatic and intelligent irrigation. Information about the pressure, humidity, temperature, and light levels is provided in part by these sensors.

Data Analytics: The data gathered from the IoT sensors cannot be stored in the normal database system. The end-to-end IoT platform and cloud-based data storage are crucial components of the smart agricultural system. These mechanisms are thought to be crucial in enabling better performance of tasks. In the IoT era, sensors are the main means of mass data collection. Using analytics technologies, the data is examined and converted into useful information. The examination of weather, livestock, and agricultural conditions is made easier with the use of data analytics. By utilizing the gathered data and technological advancements, better judgments may be made. You may obtain information on the status of the crops in real-time by using IoT devices to collect data from sensors. You may get knowledge to improve your harvesting decisions by using predictive analytics. The trend analysis aids farmers in forecasting impending weather and crop harvesting. IoT in the agricultural sector has aided farmers in preserving the fertility of the soil and the quality of their crops, improving the quantity and quality of their output.

Agricultural Drones: Agricultural drones have nearly completely transformed agricultural operations as a result of technological improvements. Drones are utilized for field analysis, planting, crop spraying, crop monitoring, and crop health evaluation. Drone technology has transformed the agriculture sector by giving it a high rise and a makeover with adequate strategy and planning based on real-time data. Drones equipped with thermal or multispectral sensors can locate the locations that need irrigation adjustments. Sensors determine the vegetation index after the crops have begun to develop and show their state of health. Eventually, the environmental effect was lessened by intelligent drones. The outcomes have been such that there has been a significant decrease in the amount of chemical entering groundwater.

Table 1. The Use of IoT in Smart Agriculture

IoT Technology	Application in Agriculture	Advantages in Agriculture
Wireless Sensor Networks	Sensors Working Together To Track Different Physical Properties	Simple Administration And Collecting Of Data From Sensors
Cloud Computing	Offers Personal Computers And Other Devices On Demand Access To Pooled Computing Resources And Data.	Data Obtained Through Cloud Computing Services, Such As Maps Of Agricultural Fields And Cloud Storage, Is Easily Collected And Managed.
Big Data Analytics	Access To Different Sorts Of Data	Discover Trends, Correlations, and Patterns In The Market, Consumer Preferences, And Other Important Data.
Embedded Systems	The System Carries Out Particular Functions Including Managing Numerous Operations Effectively And Monitoring And Regulating Them.	Costs For Production May Be Dramatically Lowered, Boosting Profitability And Sustainability.
Communication Protocols	These Protocols Enable Data Communication Via The Network In A Number Of Different Data Exchange Forms.	Simple Handling Of Massive Amounts Of Data Collected From Sensors And Cloud Storage, Cloud Computing, Etc.

6. Smart agriculture using UAV

Today, the IoT system has produced notable advancement in various industries, including farming regions. However, the communication infrastructure in agriculture, including as base stations and Wi-Fi, is woefully inadequate, which restrains the growth of the IoT in this industry[7-11]. One of the biggest hurdles when introducing the IoT in the agriculture business is that such communication arrangements and related utilities are considerably worse in developing countries and rural locations. Without a trustworthy connection setup, the data generated by the wireless sensors cannot be shared. UAVs can provide as an alternative route in such circumstances. The UAV system links to the wireless sensor network across a wide area to gather data for further processing and research [14]. The robot revolution in smart agriculture has been one of the most useful. Drones, also known as UAVs, have seen widespread application. Agriculturalists utilize drones or UAVs often for monitoring and managing farm growth. Some UAVs are being used to aggressively spray pesticides and water in arid terrain where it is difficult for people to move about and the crops are of varying heights. Additionally, UAVs, sometimes known as drones, equipped with precise sensors and high-resolution cameras, may fly over fields covering thousands of hectares. Investigation plays a very important part in all agricultural applications, but it is especially important in forestry and crop observation when it comes to covering wide areas [14]. Therefore, it is essential for agriculture production to maintain a quick, affordable, accurate, and wide surveillance system with a precise data acquisition and broadcast facility. Currently, satellites and aeroplanes are the two main methods utilized to find aerial photos of a field or farm zone. Both options are acceptable for a macro view of the landscape, but they both have serious issues with their quality when it comes to PC viewing. However, UAVs are a platform that offers a "eye in the sky," which eliminates or fixes the aforementioned issues with the micro views. The quality of photos

captured by UAVs depends on the resolution of the included cameras, which is often much higher than that of satellite photographs, and, most importantly, it is regulated in accordance with application requirements. More precisely, UAVs maintain NDVI more quickly and accurately to analyze agricultural conditions such as weed mapping, leaf evaluations, etc. and provide farmers with an immediate reaction so they can make the right moves at the right time. UAVs are thus more frequent, even if used numerous times within a same day, and are less affected by weather conditions, unless it is pouring. UAVs are considered as the precision agricultural technology of the future because of the aforementioned benefits. In addition to being impossible to calculate, some pesticide and fertilizer applications call for UAVs to deliver big payloads. Therefore, to extend the flying time in such circumstances, optimal battery usage becomes important. Numerous characteristics may be measured with this resolution to increase the drone's effectiveness. When flying, choose the proper circumstances first, such as the weather or the airflow. Successfully, try to put the best payload together and at the right position. In this situation, placing the payload close to the field, improving it in lesser quantities, and then refilling it again in its spot for placing big quantities, might be helpful. Moreover, ideal path choice plays a significant role depending on the size of the region and the frequency of visits. In this resolution, a variety of routing configurations are planned in particular for the UAVs, thus choosing and implementing the appropriate configuration can provide noticeable change. New activities like anchoring systems might be helpful since drones are required to fly with heavy payloads for UAV-based agriculture and pesticide application. When a UAV is tethered, an assembly that provides power through a lengthy cable is given so that it may fly as long as the farmers have access to backup power on the farm. This is important since it means that hefty batteries are not need to be lifted. Agriculture is now thought of as one of the most encouraging industries where UAVs might suggest numerous answers to resolving many significant and enduring difficulties.

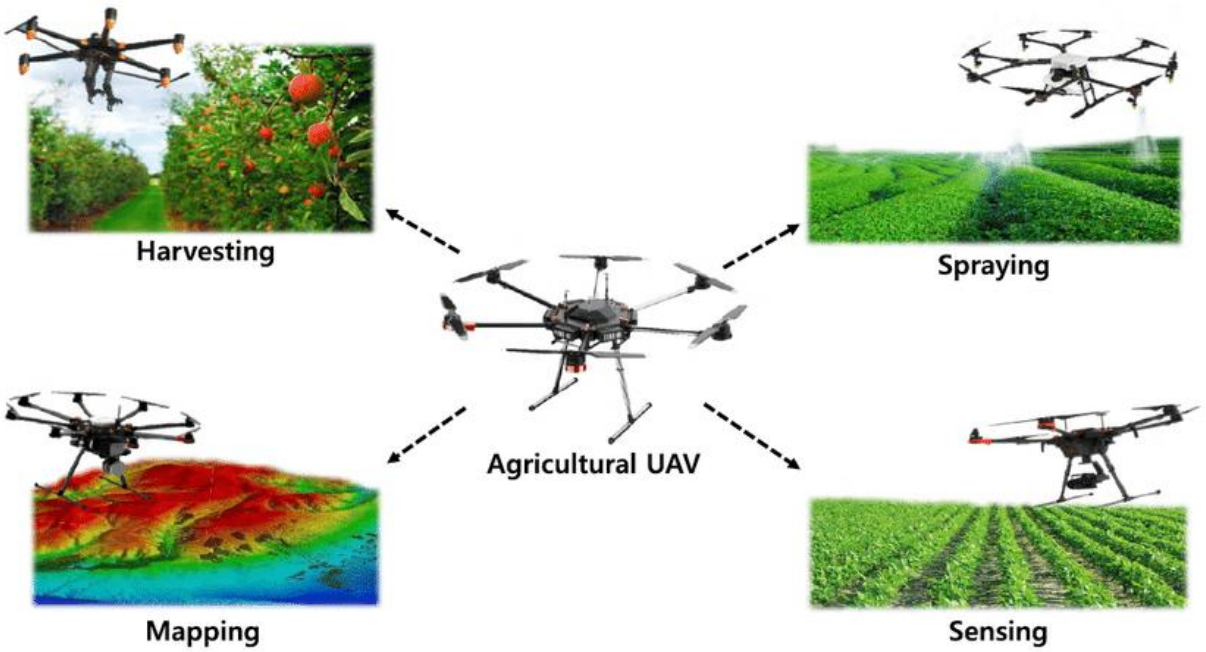

Figure 4. Various agricultural UAV types

7. Conclusion

IoT-enabled agriculture has aided in the application of cutting-edge technical answers to age-old problems. This has made it easier to reconcile output, quality, and yield. Swift action and reduced harm to the crops are guaranteed by data ingested by acquiring and importing information from the many sensors for real-time usage or storing in a database. Produce is processed more quickly and arrives to supermarkets in the shortest amount of time feasible thanks to seamless end-to-end intelligent operations and enhanced business process execution. This article presents many examples of smart agriculture, discusses the benefits and applications of using IoT and UAVs in agriculture, various communication methods, and highlights the challenges and limitations of IoT and UAV connection in distant places. The paper described the limitations of connection in terms of transmission range and communication technologies.

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