Major Applications of Smart Agriculture

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With the rise of new technologies, such as the Internet of Things, raising the productivity of agricultural and farming activities is critical to improving yields and cost-effectiveness. IoT, in particular, can improve the efficiency of agriculture and farming processes by eliminating human intervention through automation. The fast rise of Internet of Things (IoT)-based tools has changed nearly all life sectors, including business, agriculture, surveillance, etc. These radical developments are upending traditional agricultural practices and presenting new options in the face of various obstacles.

Keywords: agriculture ; land monitoring ; control strategies ; IoT ; sensors ; economic growth

1. Introduction

The Internet of Things (IoT) is an interconnected network of computing devices, people with unique IDs, and the capacity to communicate via a network without human interaction. The Internet of Things (IoT) intends to connect the physical and virtual worlds by interacting and exchanging data via the internet. Linked industries, smart cities, smart homes, smart energy, connected vehicles, smart agriculture, connected buildings and campuses, health care, and logistics are all examples of IoT applications [1]. The increasing need for food, both in terms of quantity and quality, has required the development and modernization of the agricultural sector. The “Internet of Things” (IoT) is a promising set of technologies that may be used to provide a variety of agricultural modernization solutions. Scientific institutions, research institutes, and the agricultural sector are racing to provide more and more IoT solutions to agricultural business stakeholders, laying the foundation for a clear role when IoT becomes a mainstream technology [2]. The world’s biodiversity is anticipated to support between 9.4 and 10.1 billion people by 2050, increasing the need for specialized food production zones, especially for harvesting and livestock. This means that by 2050, global food production will have to grow by 70% [3]. Crop production is increasingly crucial in agriculture, with commodities, such as cotton, wheat, gum, and others, playing significant roles in many nations’ economies.

In 2019, the IoT market was 690 billion dollars and was projected to be 1256.1 billion dollars by 2025 with a 10.53% CAGR globally from 2020 to 2025. Solutions are needed to assure timely and regular agricultural growth and yield due to the combined effects of a growing population, natural weather unpredictability, soil degradation, and climate change. Farm management, animal monitoring, irrigation control, greenhouse environmental control, autonomous agricultural machinery, and drones are examples of IoT applications in agriculture, all of which contribute to agrarian automation. It also demands contributing to agricultural food production’s long-term viability. Land appraisal, crop protection, and crop yield projection, according to these needs, are essential to world food production [4]. Farmers, for example, can manage field environments in real-time and more effortlessly regulate fields using wireless sensors and mobile networks. Farmers may also utilize IoT technology to capture essential data, subsequently creating yield maps that enable precision agriculture to produce low-cost high-quality crops [5]. **Figure 1** depicts the smart precision agriculture cycle.

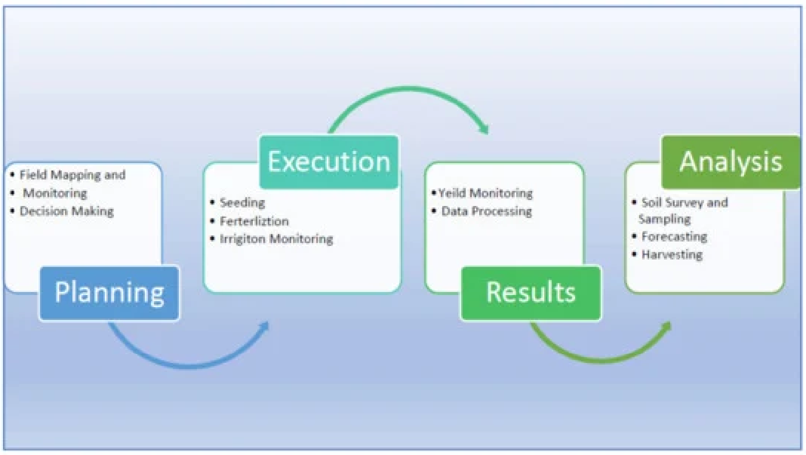

Figure 1. Smart precision agriculture cycle.

Smart agriculture is becoming increasingly important to farmers in the modern day, and it will become even more critical in the future to ensure proper field expansion and crop output. Unfortunately, traditional farming methods are not up to the task of meeting rising demand. As a result, the ground stays barren and devoid of fertility due to poor utilization of nutrients, water management, light, fertilizers, and pesticides. Crop diseases, water shortage, irrigation, and pesticide control monitoring are only some of the challenges that different IoT automation and control systems can efficiently address [6]. This is why contemporary agriculture employs smart equipment and tools from sowing through crop harvesting, storage, and transportation. The operation is smart and cost-effective due to its accurate monitoring capabilities and fast reporting using a range of sensors. Autonomous drones, harvesters, tractors, satellites, and robots are now complementing agricultural equipment. Sensors may be instantly placed and begin collecting data, which is then immediately available for further analysis over the internet. By enabling reliable data gathering at each place, sensor technology allows crop and site-specific agriculture [7]. Using advanced control methods to automate agricultural activities has increased crop production while also improving soil fertility.

The following are the significant contributions made by this study:

- The world's expectations of the agriculture industry, based on existing IoT approaches for providing solutions and new applications and technology.
- Identification of numerous application fields, as well as a summary of the most recent state-of-the-art literature on IoT technology.
- The Internet of Things' task is to address these constraints and other challenges, such as resource scarcity and precise usage, climate change, etc.

2. Major Applications of Smart Agriculture

Precision farming, animal monitoring, and greenhouse monitoring are a few agricultural businesses utilizing the Internet of Things. Every element of traditional farming operation may be substantially improved by combining cutting-edge sensors and Internet of Things technology. At the moment, the Internet of Things' (IoT's) and wireless sensors' harmonious incorporation into smart agriculture can catapult agriculture to formerly inconceivable heights. Appropriateness of land, pest monitoring and control, irrigation, and yield optimization are just a few of the conventional agricultural issues that IoT may assist in resolving through the implementation of smart agriculture approaches [7]. **Figure 2** illustrates the comprehensive paradigm of smart agricultural monitoring system applications, facilities, and sensors. Agriculture applications are classified as IoT agricultural apps, smartphone-based agricultural apps, and sensor-based agricultural apps. Wireless sensor networks (WSNs) have recently been used to enable IoT applications for smart agriculture, including irrigation sensor networks, frost event prediction, precision agriculture and soil farming, smart farming, and unsighted object recognition, among others [8]. Significant instances of how new technology assists in the general improvement of efficiency at various stages are included here.

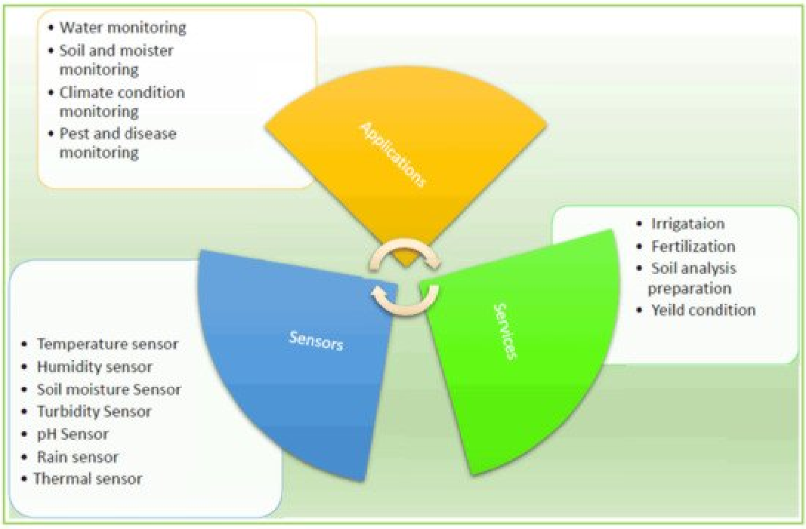

Figure 2. General paradigm of smart agriculture.

2.1. Monitoring of Soil Moisture and Water Levels

Soil monitoring has developed into one of the most challenging agricultural areas, both for manufacturers and farmers. Numerous environmental issues associated with soil monitoring affect agricultural yield. When these sorts of obstacles are correctly identified, farming patterns and methods become readily understandable. The soil's moisture content, wetness, fertilizer application, and temperature trends are all being monitored. Soil's moisture environment management system uses soil humidity and moisture sensors. By proposing an appropriate fertilizer approach, the results of a soil monitoring test report assist farmers in increasing crop yield [9]. The sensor can read both analog and digital outputs. The judgment is made based on data collected from sensors and compared to predefined threshold levels. The soil moisture sensor is used to regulate the irrigation system's automatic operation. When the moisture level goes below the threshold value, the water pump is triggered [10].

Soil mapping enables you to sow many crop types in the same field, allowing you to match better soil characteristics, such as seed compatibility, sowing timing, and even planting depth, as certain crops are deeply rooted while others are not. Additionally, growing many crops concurrently may result in more prudent agricultural practices, such as resource conservation. The system is composed of a distributed network of soil moisture and temperature sensors located in the root zone of the plant, as well as rain sensors located in various zones. The microcontroller collects and transmits all sensor data and information. In addition, a temperature and soil moisture threshold algorithm will be devised and implemented in a microcontroller-based gateway to regulate the amount of water given to the fields. Finally, the user is provided with control via an IoT module based on rain sensor data to interrupt or restart water flow as needed [11].

If the field contains an adequate amount of water, no water will be pumped into it. However, when the soil's water moisture content falls below a predetermined level, water is pumped into the field until the desired moisture content is attained. The DHT11 sensor monitors the field's temperature and humidity. In addition, a PIR motion sensor detects when an intruder (human or animal) enters the area. Consequently, sensor values are continually monitored and displayed on the farmer's mobile device through a GSM sim900A module, which includes a sim card with a 3G data pack and adds IoT capabilities to the system [12].

2.2. System of Irrigation Monitoring

Numerous studies have been conducted on a smart irrigation system. Food production technology must significantly improve to keep up with the growing demand for food. Numerous experts have worked diligently to create an alternative to irrigated farming. These efforts, however, have not yet resulted in a feasible solution to the irrigation system's present problems. At the moment, crop irrigation is carried out manually and by established customary practices. When crops are given less water, they grow slower and absorb less calcium. Frequent irrigation kills roots and wastes water. As a result, accurate irrigation of crops becomes a considerable difficulty [13]. A smart irrigation management and monitoring approach is developed to enable autonomous delivery of sufficient water from a tank to field crops. Automatic sensor systems are cost-effective, offered for determining whether plants require watering based on information gathered from monitoring and regulating the soil water levels to minimize dryness or overflow [14].

Kamaruddin et al., 2019 [15] developed an Internet of Things (IoT)-based wireless sensor network (WSN) architecture that manually or automatically administers and monitors the irrigation system. The proposed method used NRF24L01 and Arduino tools as the communication network transceiver and CPU. The soil moisture sensor data will be sent to the base station via NRF24L01. Then, the sensor node's data will be sent to the cloud server through the base station. This project utilized Thingspeak as a cloud server to store all data in a database and connect it to an Android application.

2.3. Fertilizer Administration

Akshaya et al., 2020 [16] proposed an IOT-based technique and upgraded the previous system, which predicted agricultural yields using backpropagation and a random forest algorithm. It recommends fertilizer application rates and exclusively monitors atmospheric data via a mobile network and pump on/off action. The suggested technique utilizes a segmented tank to collect NPK fertilizer and water. The user can select one of three modes (manual, auto, or smart). In manual mode, the user is provided with the fertilizer and water ratios for well-known plants and fertilizers. In auto mode, all required is to know the plant's name to select the appropriate fertilizer and water ratio. Finally, in smart mode, if the user cannot recognize the plant's name, fertilizer ratio, or water, the plant's name, fertilizer ratio, and water will be recommended automatically. The IoT module will continuously collect information on the temperature and soil moisture. The information collected will be stored in the IoT cloud. The mobile phone will inform you whenever the given data changes and the needed fertilizer ratio will be shown on the liquid crystal display.

2.4. Crop Diseases and Pest Control

Human operators frequently monitor insect pests via time-consuming and costly on-site inspections, which results in low spatial and temporal resolution. Remote monitoring has been possible due to advancements in remote sensing, electronics, and informatics. Monitoring costs and effectiveness can be optimized through the deployment of camera-equipped traps. With minimum human intervention, image analysis algorithms can locate and count insect pests captured in traps automatically.

Reddy et al., 2019 [17] created an IoT-based system for disease and insect pest management in agriculture and the prediction of plant climatic factors. The integrated sensors help in the measurement of soil and atmospheric moisture and humidity. These features help determine the environmental conditions in which the plant flourishes and the plants' illnesses. It detects disease on the field and sprays prescribed insecticides. Web cameras take images that are then preprocessed to include RGB to grayscale conversion, defect detection, image scaling, image enhancement, and edge detection. SVM is utilized to categorize characteristics generated from Citrus Canker diseases, such as energy, kurtosis, skewness, and entropy (damaged Lemon crop). The Arm7 microcontroller is used for hardware, power, sensors, and motor driver control. Once the illness is identified, the program will propose fertilizers and transmit the results to an LCD and the recommended fertilizers. By pump, the fertilizers will be sprayed on the diseased leaves. This study was confined to the lemon plant to demonstrate that the same method may be used for various crops with favorable outcomes in the future.

A solution is presented for forecasting and detecting grape disease using the CNN approach and real-time gathered data on environmental factors. First, the CNN technique is utilized to analyze the leaf images. Then, different layers of the CNN method are used to create the image. Finally, it is scaled to a specific resolution before data is sent into the CNN layers for training and testing. The suggested algorithm was evaluated on four diseases known to have a higher effect on grape production. The diseases include esca black measles, anthracnose, leaf blight, and black rot. This gadget not only detects but also forecasts illnesses based on historical weather data. On the other side, the readings from the humidity, temperature, and soil moisture sensors are transferred through Raspberry Pi to Microsoft's Azure Cloud. Following this, the sensor readings are used to anticipate the illness using a trained linear regression model. Based on the findings of the preceding detection and prediction stages, suggestions for appropriate fertilizers in the right quantities will be provided to minimize fertilizer misuse and cost savings [18].

To detect pests in rice during field production and avoid rice loss, the Internet of Things supported a model-based UAV with the Imagga cloud offered. The Internet of Things-based UAV was developed on AI mechanisms and the Python programming prototype to transmit rice disease images to the Imagga cloud and supply insect data. The Approach identifies the disease and insects by integrating the confidence ratings of the labels. The label identifies the objects in the images. To determine the pest, the tag with the greatest confidence results and more than or equal to the threshold is chosen equal to the target label. If pests are discovered in the rice, statistics will be transferred to the field owner directly to take preventative actions. The suggested method is capable of detecting all pests that influence rice production. On the other hand, this research attempted to minimize rice waste during production by conducting insect monitoring at regular intervals [19]. **Table 1** summarizes many current smart agricultural applications.

Table 1. Selected applications based on smart agriculture.

Ref.	App	Description
[7]	Soil Analysis	Land management offers long-term promise based on climate, geography, and reasonably stable soil characteristics (like soil texture, depth, and mineralogy). This application aids farmers in better understanding the potential of their land and climate variations alteration and extenuation measures.
[9]	Farm Manager	Farm Manager App helps the farmers to decide which techniques should apply before planting starts. This app views, organizes, and edits all information about your field like yield, planting, and spraying conditions without your mobile phone.
[7]	Pest Management	By collecting pest occurrence information from farms, Village Tree provides smart pest control solutions. In addition, it employs a crowdsourcing strategy, sending images and location data to other farmers who may be affected.
[9]	Agrippa	Farmer can generate electronics maps of field, keep a history of growing crops in the field (e.g., planting, fertilizing, harvesting, warehouses, gas station), and track the location of objects in the field (e.g., soil sampling for agrochemical laboratory) by eFarmer Application.
	Semios	Covers network coverage, orchard pests, frost, diseases, and irrigation. Event notifications are sent out in real-time as part of the monitoring services.

Ref.	App	Description
[7]	**Fertilizer Management**	**Eco Fert assists with fertilizer management so that it may be used to its full potential. It determines the optimal fertilizer mixture created to cover the needed nutrient suspension and considers the demands of diverse yields. In addition, it considers the cost of fertilizer based on current market pricing.**

2.5. Yield Monitoring, Forecasting and Harvesting

The AWS IoT platform has been proposed for crop prediction using temperature and rainfall monitoring. The Raspberry Pi is utilized as a gateway for remote monitoring in this study. Raspberry Pi can connect with sensors to operate applications, such as the DHT11 Temperature Sensor and Soil Moisture Sensor, which forecasts temperature and rainfall ranges. The gateway is integrated with Amazon Web Services' (AWS) IoT platform. MQTT is a messaging protocol that allows for various messages across distant connections [20].

The study reported establishing an autonomous greenhouse smart aquaponics management organized on temperature via the use of an Android-based monitoring and automatic correction system and a Raspberry Pi-based plant growth monitoring system. Real-time data is collected using the light intensity sensor and the ambient temperature and humidity sensors. Additionally, the pH and temperature of the recirculating water are monitored. Suppose the data acquired is beyond the threshold range. In this case, the system quickly engages the correction devices, which comprise a peristaltic buffer device, an aerator, an evaporative cooler, inlet and exhaust fans, and grow lights. The internet remote access function enables real-time data transmission and receipt through the android app amongst the smartphone and computer system. This study compared plant development in smart aquaponics to traditional agriculture based on soil systems employing image processing in two investigational operations. Following record collection, it was determined that the smart aquaponics system achieved greater output than conventional agriculture monitoring. As lettuce, mustard greens, and pak choi are produced in a smart aquaponics system vs. traditional soil-based farming, this study focused exclusively on lettuce, mustard greens, and pak choi [21].

A tree topology was used for the WSN-enabled agricultural monitoring system to improve performance. A cheap sensor node like a commercial sensor or a NodeMCU module transmits data to the control unit over Wi-Fi. Fertilizer, fertigation improvement, and agricultural operations are monitored by data processing and thresholding. The incorporation of cost-effective ICT technology with traditional crop management or weather monitoring and sensor data created the agronomic model. Minimal environmental impact from crop growing was achieved as a consequence of large fertilizer and water savings [22].

2.6. Climate Conditions Monitoring

In farming, the weather is extremely important. Incorrect climate knowledge can have an impact on crop quality and quantity. On the other hand, farmers may use IoT solutions to put sensors in the field, including humidity sensors, temperature sensors, rainfall sensors, and water level sensors, to collect real-time data from the environment. These sensors monitor the state of crops and the environment in which they grow. If a worrying environmental situation is discovered, it is either automatically corrected or a warning is sent to the farmer.

Greenhouses created an Internet of Things-based weather station to address the cost and accuracy issues. The TI CC2650 Sensor Tag and IBM Cloud Platform continuously monitor weather and abiotic factors, transfer the detected values to the cloud, and send e-mail notifications when values deviate. As a result, this study may be expanded to include the use of ML model-based classification training to categorize a plant's health as excellent, moderate, or terrible based on the average temperature, humidity, light intensity, and air pressure. This would help to clarify abstracts about a plant's health to a larger level and might aid in keeping the plants' health in good shape [23].

Ariffin et al. [24] used an autonomous temperature control system to address the drawbacks of traditional growing methods, which are expensive, have low yields, and need a lot of care. The suggested IoT-based architecture was evaluated in a real-world setting at the Bandar Puteri Centre of NASOM (National Autism Society of Malaysia). The ideal temperature for oyster mushrooms is between 20 and 30 °C, with a humidity level of 70 to 80%. Two sensors were installed in the mushroom house's center and corner to detect temperature and moisture, then communicated to a remote monitoring station through a microcontroller unit for further action. The results of the six-day experiment revealed that an effective automatic monitoring system, which can regulate the farm's home while reducing resources and human labor, was developed. The mushroom home, IoT control box, and Web Client interface were all designed within the system. As a result, the mushroom house provided a regulated environment for mushroom growing as well as protection from pests and insects. The climate control system, which automates controlling the ideal environment for oyster mushroom production, was housed in the IoT control box.

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