

Recent Advancement and Trends in Mechanical Automation, Sensing Devices, and Internet of Things (IoT) in Smart Agriculture

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Abstract-India is a developing nation with an annual population growth rate of 1% according to the World Bank Data (2020). Presently, the agricultural sector has successfully managed to meet the population demand and has contributed in annual GDP growth rate of the country. In the coming few decades, the agricultural yield through traditional techniques might fail to meet this growing demand. However, developed countries have managed to upgrade their conventional farm machinery to mechanized devices. The application of sensors and IoT with web-based portals and mobile applications has overcome the environmental challenges of climate change. The innovations in cutting-edge technology have transformed the agriculture sector globally. The application of high-quality sensors in irrigation, fertilizers production, and disease prevention in different crops has increased the overall production efficiency. The application of IoT to acquire information on crops, soil, and the environment has proved to be an efficient tool in rural areas with fewer resources and expertise. It also establishes the intelligent networking systems using GPRS, Zigbee, WIFI, Bluetooth, etc., for easy handling and transportation of agricultural products. The decision support system (DSS) and automatic control system (ACS) reduce time and human interference as well. The present study discusses the potential technology in the field of agriculture to transform rural India. The study emphasizes technology in crucial areas, such as agriculture, renewable energy, information and communication technology (ICT), and sensors for transforming rural India into a developed Nation.

Keywords: Rural Development, Smart Village, Automation, Renewable energy, Sensors

I- INTRODUCTION

Human survival needs agriculture as a source of living. It also imparts livelihood to more than 10% of the global population [1]. In developing countries like India, agriculture is a vital source of livelihood for rural residents with an annual population growth rate of 1% according to the World Bank Data (2020) [2]. As per the study, the global population count is expected to rise more than 31% by 2050, and this will demand an increase in crop production yield [1]. The traditional farming method has failed to meet this growing demand, resulting in the need for advanced technologies and techniques. Researchers across the globe have successfully developed technologies for farming to enhance crop yield [3,4,5]. Advancement in sensors and automation tools in most developed countries have improved farming methods [6]. Agriculture 4.0 is a revolutionary mission led by most developed countries to transform agriculture into a more innovative form [2]. The mission implies the application of machinery with automation, Internet of Things (IoT), Big Data Analysis, Artificial Intelligence (AI), Unmanned Aerial Vehical (UAVs) in monitoring and handling crops. It provides excellent production with minimal cost, labor, and the least environmental pollution [2]. Agriculture 4.0 has

also motivated private companies to participate and develop tools for farming and irrigation. Besides this, the application of thermal imaging, remote sensing, machine learning, UAVs, and Wireless Sensors Networks (WSN) has also enhanced crop production and agriculture practices[7]. However, the process has failed to remediate the issues related to management, training, network connectivity, data storage, data sharing lack of essential resources, such as electricity, light, and water. The recent advancement in agriculture using AI and IoT has caused the following benefits: (a) easy monitoring of crop field, (b) in-house command-driven system to start and haul the process (operating water pump from houses in a radius of 10 km), (c) on-field data collection of soil sample and crops using sensing device, (d) cost-effective and easy understanding, (e) pre-alarmed system in case of heavy rain and pump operation, (f) Managing the process of harvesting and crop storage, (g) immediate scientific and technical expertise to farmers, (h) increase in marketing, sales, and production. Apart from the above benefit, the technology has still failed to resolve the operation difficulties to local farmers. Even with rapid advancement in technology, there was a lack in the concept of Smart Sustainable Agriculture (SSA), which can be accomplished by surpassing complex obstacles in controlling and operating AI, data management, collection, and interpolation. The present study explores existing AI/IoT-based technology; its application, benefits, and limitation in SSA, as represented in **Fig 1**.

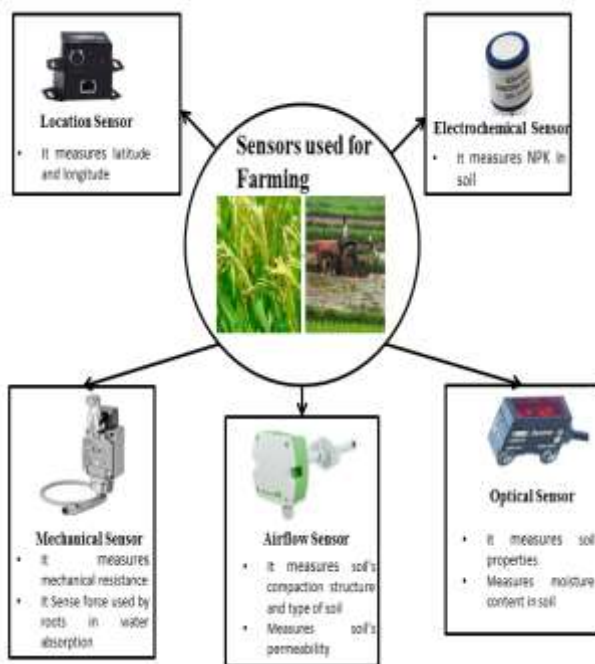


Fig 1-Type of Sensor in Agriculture

II-APPLICATION OF IOT, UAVS AND SENSORS IN SSA

Utilization of IoT, UAVs, Sensors are the recent technologies using in farming, which converts old practices of farming into new agricultural methods. Some of the techniques have been explained in the following sections. Moreover, the Application of smart tools and theologies in agriculture is presented in **Table 1**.

Table 1. Application of smart tools and theologies in agriculture [8]

Monitoring Parameter	Technology	Objectives
P	RFID	To develop infrastructure for tracking of agriculture supply chain.
PR, SM, W	ZigBee & GPRS	To find out real time calculation of soil moisture
PA	RFID	To improve as well as check a RFID tracking technology with measuring the rhythm of a marine species.
O, CO, N2, Ta	ZigBee	To monitor emission of greenhouse gases.
Ta, Ha, F, FC	WiFi	Identify infections through feed as well as fluid checking, and identify increase in temperature gradient.
T, DO	WiFi	To present actual time monitoring of the water quality.
Ta, Ha	WiFi	To develop system to determine physical chemical property of soil and crops
Ta, Ts, Hs	WiFi & ZigBee	To determine moisture content in agriculture soil.

(Abbreviations: W-water level; P-production information; RH-relative humidity; SM-soil moisture; Ta-air temperature; NT-nitrogen; PS-phosphorous; Hs-

solihumidity; Ha- air humidity; F-feeding amount; CO-carbon monoxide; O-oxygen sensor; N2-nitrogen dioxide; PR- precipitation; PA-position; FC-field condition; T-temperature; DO-dissolved oxygen; Ts-soil temperature)

2.1 IoT in Smart Energy System

The application of (IoT) in energy management and similar trend has met the demand of the growing population. These new IoT-based devices increase performance efficiency and productivity to resolve issues in agriculture, energy, etc. The IoT was upgraded during the industrial revolution in 21 st century [9]. The IoT application is not limited to energy management only but it exceeds for multiple sectors such as infrastructure, electrical appliances, mechanized machinery [10,11,12]. Observing energy [13], energy harvesting [14], energy use and optimization schedule [15], energy internet [16], efficient data collection [17], energy integration [18], industries and intelligent homes [19,20,21,22], smart grid applications [23,24], energy sustainability [25], auto-energy management [26], and so on. The past studies have claimed potential benefits from IoT-based technology in different domains of research. Technology has vast potential to enhance security and connectivity with real-time problem solutions, which can resolve the real-time problem of monitoring and handling at agricultural farmland.

2.2 UAVs in Farming

Remote sensing includes the application of satellites, aircraft, or small analytical devices to collect, process, and interpret the data from soil and other resources in farming. Sensor nodes intercept the different arena's electromagnetic spectrum and reflect into the atmospheric plane [27]. Generally, optical remote sensing is preferred in agriculture. Initially, it captures energy from an atmosphere of the desired location and creates an image with the help of a visible sensor and near-infrared sensor [28]. Drones are used to collect information from the radiation of the visible spectrum that reflects from the ground. In farming, high-resolution cameras and smart sensors are used as per the requirement of data digging. Moreover, to recognize the amount of water in the plant body thermal sensor is used. It detects because leaves have more water displayed in the blue spectrum in the heat map [29]. In numerous industrialized areas and the agricultural sector, IoT, Cloud computing, Big Data, etc., have made inspiring growth; however, IoT has inadequate network facilities

like cellular networks and Wi-Fi routers. Wireless sensors cannot transmit real-time data on the cloud due to the deficiency of a solid communication structure and gathered information. At this stage, UAVs render wireless services by visiting the on-site location to collect appropriate data for further analysis.

UAVs are mainly categorized as multi-rotor and fixed rotor is shown in Fig 2. [30]. Each type has different specifications like payload capacity, hardware parts, size, range, etc. Fixed-wing drones are broadly used to cover a large area because of long-range flying ability like the eBee SQ drone [31]. On the other hand, a multi-rotor drone is preferred for fast configuration and lift off and touch down vertically. It has more advantages than the fixed-wing drone due to its easy control and it flies precisely. Additionally, the multi-rotor can fly at low altitudes to capture high-resolution photographs ex. DJI Matrices 200 and American Robotics [32,33].

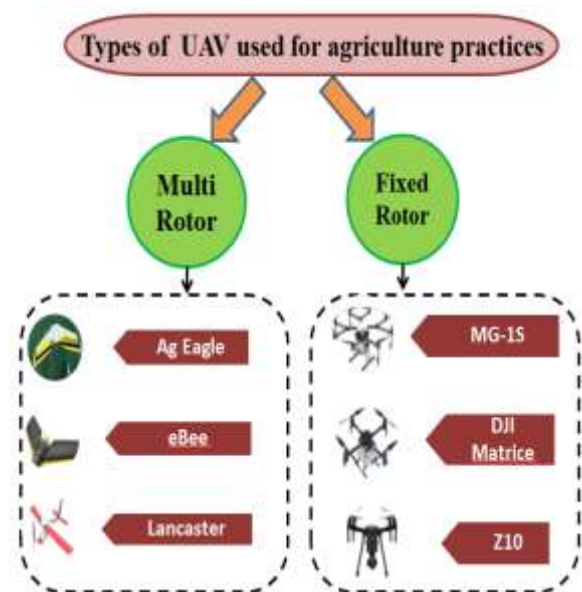


Fig 2-Classification of Drones used for Agricultural Purposes

These UAVs assist in solving many problems, whether it is huge or small. It gives service in the defense sector, agriculture, and many more. Application of advanced tool allows cost reduction and less human resources. UAVs offer soil analysis in the field before plantation, which aids to decide the crop is suitable for this soil condition or not and shows kinds of seeds and procedures of the plantation that should be used [34]. It is used for crop monitoring. This is more convenient for farmers and reliable tracking of isolated farms in real-time [35]. Body sensors and cameras are mounting to

detect underwater stress sites and provide appropriate irrigation throughout the land by sprinkling the water on UAVs. This drone technology helps to save water and detects irrigation leaks as well [36]. Moreover, it is also used for spraying pesticides on crops. Spraying the pesticides in fields by labor may lead to suffering from several diseases; for such circumstances, UAV spraying is a valuable method for farming. It is sprayed on affected areas only and helps to minimize overall spraying cost and time, so it is highly economical [37]. Sensors fitted on the drone body, such as visible light and infrared sensors, are used to identify plants' health. Sometimes plants are affected by fungus or bacteria, which deteriorate crops and reduce productivity. But this health valuation plays a vital role in protecting plants from disease [38].

2.3 IoT in Smart Agriculture

IoT has an unique identity to perform applications like monitoring, remote sensing, data storage, etc. IoT devices can exchange real-time data with other hardware modules or applications. The essential components of IoT are input and output coupling for sensors, interface for connection to the internet, memory and storage coupling, Audio/Video interface. This innovation of ICT equipments makes IoT is cost-effective for farming [39,40]. IoT devices are broadly used across the globe with a standard communication protocol. IoT uses multiple technologies to gather information or data by adopting cloud storage software, extensive data analysis, wide sensor networks, communication protocol [41]. IoT aims to connect different devices through a single internet network. It intends to unite all smart tools in the same network topology. In IoT, two kinds of computer technologies are used: i) Hardware (small modules, sensors) ii) Software (advanced algorithms). This technology has been broadly used in several areas like private sectors, bio-medical engineering, agriculture, etc., for data exchange, data transmission [43]. IoT application allows command-driven functions such as water distribution through irrigation networks. Jagey et al., 2019 designed automated irrigation system with a mobile operating mechanism. The smartphone is used to click and process the photographs near the roots of crops and then identify the amount of water [40]. Studies have also suggested that ARM9 processor was found to be appropriate for real-time functioning of drip irrigation systems.

The hierarchy of IoT application in smart agriculture is represented in **Fig 3**. The application are majorly divided

into three parts are preciseness farming, greenhouse and farm animals monitoring. IoT uses various snesors like soil sensor, pH sensor, etc. used for analysis and monitoring purpose. IoT follows communication protocols for data exchange or storage. Few countries such as USA, Russia, etc. adopted smart agricultural methods of farmig. It helps to generate more crop production for the nation.

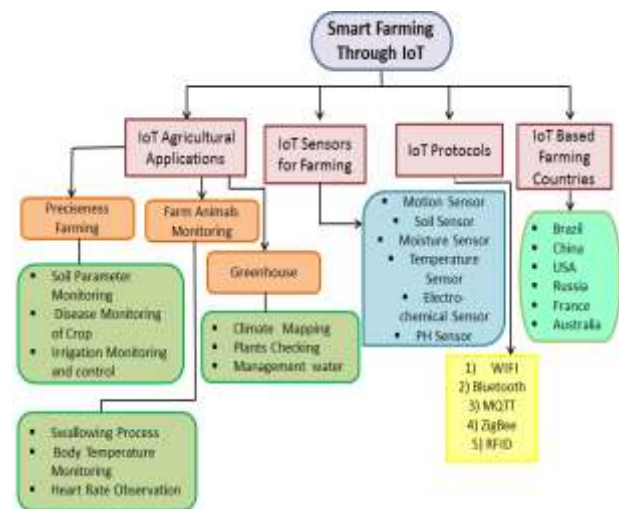


Fig 3.-IoT Based Smart Farming

2.4 Sensors in SSA

Nowadays, the application of sensors in satellite and aerial imagery has transformed the ways of doing agriculture. Smart farming is a combined optimized method in retrieving, analyzing, and storing data [44]. The application of smart sensors implies precise management, followed by productive output in crop yield and process management. The key feature implies easy processing of these methods through mobile phones, tablets, and other electronic appliances. Farmers can use these devices to analyze real-time soil properties such as moisture content, water content, electrical conductivity, pH, temperature, and wind speed [45,46,47,48,49,50]. The detailed description of the above parameters has been represented in **Table 2**. Various types of sensors have been developed in different aspects of farming. These sensors can be classified as mechanical, electrochemical, and dielectric.

Table 2. Application of Sensors

Parameter	Application of sensor
Water Content	Determines the ratio of water in soil sample. The sensor interprets the

(WC) [42]	percentage by the change in capacitance value; it ranges from 0 to 100%. The sensor must be calibrated each time before measurement
Moisture Content (MC) [43]	Similar to WC sensor. Estimate soil water tension, which helps in the interpretation of water content present near plant roots. Highly acceptable in irrigation.
Electrical conductivity [44]	Measures salt concentration, based on Faradays principle of conductivity. It prevents salt accumulation into soil and plant roots, which helps in crop yield.
pH [45]	Measures alkalinity and acidity using positive and negative electrodes emerged in solution with highly active ions and cations. This maintains soil fertility, and the range should be 5.5 to 7.5.
Weed seeker [51]	They were designed with optical light coupled with electronic components. The light reflected onto the weed measured the chlorophyll. Spray jets with chemicals are used to destroy the weed.
Temperature [46]	The sensor comprises the p-n junction diode. Measure soil temperature to control absorption, photosynthesis, and transpiration.
Wind speed [47]	Mounted depending upon crop height. The sensor determines the flow of wind depending upon the area and time.

III- CONCLUSION

The elementary requirement of the nation depends on the economic aspect, which is mainly reliable on agriculture. The primary necessity is to utilize the recent technology to mitigate real-time issues in agriculture and irrigation facilities. The present study indicated that the lack of resources and efficacy in most of the developing countries has caused mover usage of agricultural resources, such as water, rain water, and soil, which declined in crop yield. This study recommends the application of recently developed technologies to resolve

agricultural problems and make the process more innovative and reliable. At the same time, the article suggested the impacts of modern technology for better economical growth followed by an increase in GDP rate. This will also influence the change in living standards of rural residents.

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