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A Review of Smart Integrated System for Mango Orchard Management Using IoT

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Abstract

Technology advancements in machinery, equipment, and sensors have led to a new paradigm in agricultural supervision known as "smart farming," which relies on network-based, high-tech cycles. We may expect new technology, the IoT, and cloud computing to spur expansion and usher in AI and robotics in agricultural settings. Such revolutionary departures not only pose many problems, but they are also disturbing established methods of farming. The equipment and tools utilized in Internet of Things (IoT) agriculture applications of wireless sensors are explored in this research, along with the expected difficulties encountered when integrating technology with traditional farming practices. In addition, this technological information is beneficial to farmers throughout the entire crop life cycle, from planting seeds to harvesting the product. It is also being explored for potential use in packaging and transportation.

INTRODUCTION

Sustainable agriculture is a metric that quantifies the resilience and sustenance of food grains that are produced in an environmentally favorable manner [1]. Sustainable agriculture is instrumental in the promotion of agricultural practices and methods that promote the sustainability of farmers and resources. It is economically viable and guarantees a natural and healthy environment, conserves water resources, enhances land biodiversity, reduces soil degradation, and maintains soil quality [2]. Sustainable agriculture is instrumental in the preservation of natural resources, the prevention of biodiversity loss, and the reduction of greenhouse gas emissions [3]. Sustainable agriculture farming is a method that enhances the efficiency of farming while simultaneously preserving the environment and ensuring that the basic requirements of future generations are not compromised. The fundamental achievements of smart farming in the context of sustainable agriculture include the management of nutrient deficiency in crops, the prevention of pests and diseases, the recycling of materials, and the harvesting of water, all of which contribute to a safer environment. Waste emissions, the use of fertilizers and pesticides, degraded deceased plants, and other factors all contribute to the contamination of living organisms, which are dependent on the nature of biodiversity. The emission of greenhouse gases has an impact on the environment, humans, animals, and vegetation. Consequently, it is necessary to create a more favorable environment for living organisms [4] (Figure 1). In India, agriculture is the most significant contributor, accounting for 18% of the gross domestic product and employing approximately 57% of the population in rural areas. Despite the fact that India's total agronomic output has increased over the years, the number of cultivators has decreased from 71.9% in 1951 to 45.1% in 2011 [5]. According to the 2018 Economic Survey, the proportion of agricultural laborers in the total workforce will decrease to 25.7% by 2050. In rural areas, farming families are progressively losing the next generation of farmers due to the high costs of cultivation, low per capita productivity, inadequate soil maintenance, and migrations to a non-farming or more lucrative occupation. The world is currently on the brink of a digital revolution, and it is the opportune moment to integrate wireless technology into the agricultural landscape in order to facilitate digital connectivity among producers. This document is a template. An electronic copy can be downloaded from the conference website. For questions on paper guidelines, please contact the conference publications committee as indicated on the conference website. Information about final paper submission is available from the conference website.

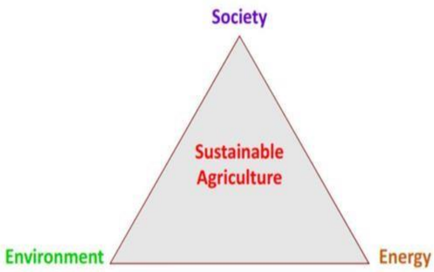

Figure 1. Factors of sustainable agriculture.

Regrettably, not all parts of the Earth's surface are suitable for agriculture due to various restrictions, such as: soil quality, topography, temperature, climate, and most relevant cultivable areas are also not homogenous [6]. Further, existing farming land is fragmented by political and fiscal features, and rapid urbanization, which consistently increases pressure on arable land availability (Figure 2). Recently, total agricultural land used for food production has declined [7]. Furthermore, every crop field has different critical characteristics, such as soil type, flow of irrigation, presence of nutrients, and pest resistance, which are all measured separately both in quality and quantity regarding a specific crop. Both spatial and temporal differences are necessary for optimizing crop production in the same field by crop rotation and an annual crop growth development cycle [8]

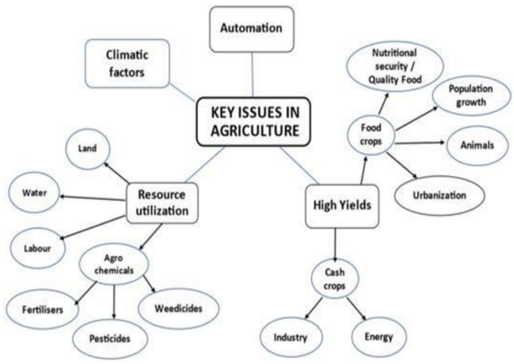

Figure 2. Important technological concerns in farming

Typically, different crops have different traits, or farms grow the same crop everywhere, thus each location needs its unique set of data to determine how to maximize productivity. To solve these problems and increase output while decreasing land use, new technological approaches are required. As part of their regular farming routine, traditional farmers would often visit their fields at various points during the life of a crop in order to assess its status [9]. Farmers can now see what's happening in the field with pinpoint accuracy thanks to modern communication and sensor technology, even when they're not physically there. From seeding until harvest, smart instruments may be used with more precision thanks to wireless sensors that detect problems early on and keep an eye on the crops [10]. Thanks to accurate monitoring made possible by the timely deployment of sensors, the entire farming operation has become smart and cost effective. Minimal environmental effect from the numerous autonomous harvesters and robotic weeders. By using wireless connection, sensor technology allows farmers to remotely monitor their crops' demands and requirements, allowing them to take action even when they aren't physically present in the fields [11]. and unmanned aerial vehicles (UAVs) utilize sensors to gather data at frequent intervals. Nevertheless, technical solutions for sustainability are severely needed due to the enormous size of agriculture.

SMART FARMING

The traditional agricultural era 1.0 encompasses the techniques of ancient agriculture, which were associated with the cultivation of land for the purpose of food production and animal breeding [12]. This mostly relied on the use of animals and human labor. When working the land, simple implements like sickles and shovels were utilized. Because manual labor was the principal method of operation, productivity remained low (Figure 3)

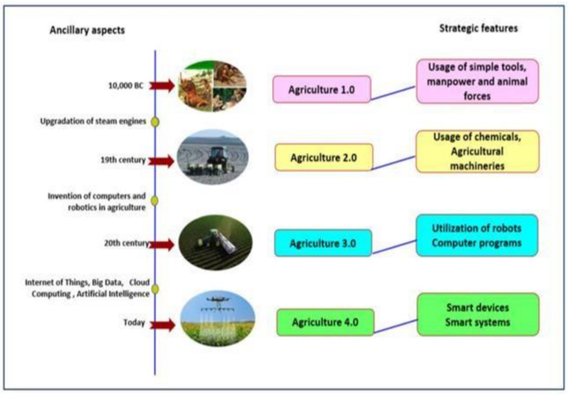

Figure 3. Structure for an Agricultural Decision Support System.

New forms of agricultural technology, such as steam engines, emerged in the nineteenth century. Farmers began the agricultural age 2.0 with the widespread use of agricultural technology and abundant chemicals, which boosted the efficiency and output of farms. Chemical pollution, environmental destruction, resource waste, and excessive energy use are some of the significantly negative consequences that emerged at the same time. The exponential development of computing and electronics in the twentieth century ushered in the third industrial revolution in agriculture. The use of robotics, computer-controlled agricultural equipment, and other technological advancements has improved the productivity of farming. Through more equitable allocation of labor, more accurate irrigation, less chemical use, site-specific fertilizer application, more effective pest control methods, etc., the problems that had developed during agricultural period 2.0 were addressed, and regulations were adjusted to accommodate agricultural era 3.0. Now is the time for the next generation of farmers to embrace cutting-edge technology like the Internet of Things (IoT), big data analytics, artificial intelligence (AI), cloud computing, remote sensing, etc., ushering in the agricultural era 4.0. The development of inexpensive sensor and network platforms has greatly enhanced agricultural activities thanks to the use of new technologies. These platforms aim to optimize production efficiency, reduce energy and water usage, and minimize environmental effects [13]. The use of big data in smart farming enables farmers to make informed decisions by providing them with comprehensive overviews of current agricultural conditions [14]. To aid farmers in making the best decisions, real-time programming is built using AI concepts and integrated into IoT devices [15]. Through the use of cutting-edge technology, smart farming encourages precision agriculture and gives farmers the ability to keep tabs on their plants from a distance. With the automation of sensors and technology, smart farming has made the farming workforce more efficient, which helps with agricultural processes like harvesting and crop yields [16]. A technological revolution is taking place in agriculture as a result of these technologies, which automate hitherto manual farming processes. Modern agricultural technology has changed farming as we know it, with the Internet of Things revolutionizing long-established practices [17]. "Smart farming" is a relatively new methodology that makes use of ICT to maximize output while decreasing labor needs on farms [16]. The farmers' needs are identified and appropriate solutions are chosen with the use of modern information and communication technology (ICT) tools, including the Internet of Things (IoT), GPS (Global Positioning Systems), sensors, robotics, drones, precision equipment, actuators, and data analytics. Decisions are made more accurately and promptly, and crop output is improved, thanks to these improvements. Smart farming technology have been suggested by various poor nations and international organizations as a means to enhance agricultural production [18]. The use of sensors allows for more precise crop monitoring at all times, allowing for the early detection of any undesirable conditions. From planting seeds to harvesting, storing, and transporting harvested crops, modern farming makes use of smart tools. The operation has become more effective and profitable as a result of the accurate monitoring capabilities brought about by the proper usage of a wide array of sensors. Furthermore, for each location, there are sensors that swiftly gather data, which is immediately accessible online for additional assessment; these sensors also enable crop and site-specific agriculture. In order to enhance spatial management practices that boost crop production while avoiding the overuse of pesticides and fertilizers, smart agriculture and monitoring tackle numerous problems connected to crop production, including changes in soil properties, climate factors, soil moisture, etc. [19].

INTERNET OF THINGS

The ANN models in smart irrigation water management (SIWM) regulate irrigation scheduling support systems (DSS) and offer data on irrigation efficiency, water productivity index, and irrigation water demand and supply on a real-time basis. Climate-smart agriculture (CSA) is an upcoming technology, especially in developing countries, due to its potential to improve food security, farm system resilience, and lower greenhouse gas emissions [20]. Smart agriculture technology based on IoT technologies has many advantages in all agricultural processes and practices in real-time, including irrigation, plant protection, improving product quality, fertilization, disease prediction, etc. [21]. The benefit of smart agriculture lies in its collection of real-time data on crops, the precise assessment of soil and crops, remote monitoring by farmers, supervising water and other natural resources, and improving livestock and agricultural production. Therefore, smart agriculture is considered to be the progression of precision agriculture through modernization and smart methods to attain various information of farm activities that are then remotely managed, and reinforced by suitable alternative real-time farm maintenance solutions. The advantages of smart agriculture include better livestock and agricultural output, accurate soil and crop assessments, remote monitoring by farmers, and supervision of water and other natural resources. Consequently, smart agriculture is seen as the next step in precision agriculture, utilizing current technology and smart methods to gather data on different farm activities. This data may then be remotely managed and supported by appropriate real-time farm maintenance systems.The Internet of Things (IoT) plays an essential role in many farming tasks, including data acquisition, smart object use, cloud-based intelligent information, decision-making, automation of agricultural operations, and the use of communication infrastructure (Figure 4).

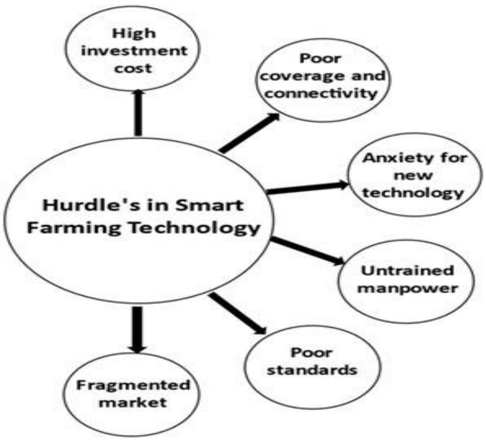

Figure 4. Problems with putting smart farm technologies into practice

By connecting various devices and networks, the Internet of Things (IoT) allows for remote data retrieval and plant and animal monitoring. Farmers can now evaluate the weather and predict their production levels with the use of sensors and tools. More than ever before, the Internet of Things (IoT) is contributing to water harvesting, flow amount monitoring and control, agricultural water requirement assessment, supply timing, and water conservation [26]. Through the gateway's cloud connectivity and sensors, it is possible to remotely monitor the water supply and soil conditions according to the needs of plants [27]. Internet of Things (IoT) technology has helped farmers reach a new level in modern agriculture, even if it is impossible to personally monitor and inspect every plant to fix nutrient deficiencies, pests, and diseases [28]. The expansion of the internet of things (IoT) has recently been a game-changer in the agricultural industry, especially in terms of the sector's communication infrastructure. Automation of agricultural processes is one example of this trend, along with the linking of smart items, remote data collecting, the use of sensors and vehicles connected via mobile devices and the internet, intelligent analysis in the cloud, interfaces, decision-making, and so on. Optimizing resources, reducing climate change's impact, and increasing harvest yields are just a few ways in which these proficiencies have transformed farming. Different types of crops and fields have prompted researchers to suggest a wide range of approaches, infrastructures, and tools for tracking and communicating crop data at various phases of development. A wide variety of vendors supply various tools for data collection and distribution, including communication devices, sensors, robotics, heavy machinery, and drones. To regulate the use of technology to maintain food and environmental safety, groups in the food and agricultural industries and other government agencies create rules and regulations [29,30].

An Introduction to Internet of Things Use Cases in Agriculture Traditional agricultural practices, techniques, implements, crop pests and illnesses, etc., may be found in one place on this userfriendly, low-cost tracking platform that also allows for interactive data collection. This data is essential for sustainable agriculture. Users are able to access the data easily through many devices, including computers and mobile phones, thanks to interactive agriculture [31]. 1. Reliable Prediction Models: The agricultural industry is known for its unique characteristics, which include variety, complexity, spatial and temporal unpredictability, and uncertainties regarding the best harvesting methods and infrastructure. 2. 3. 4. Scalability: The outcomes must to be scalable because there is a range in farm sizes. It is recommended that the placement and testing plans be gradually expanded while keeping costs down. Price should be reasonable with substantial aid since affordability is critical to agricultural success. An acceptable price could be achieved for standardized platforms, goods, instruments, and infrastructure. Strong economic pressure and severe competition on a global scale make the sustainability problem a critical one.

TECHNOLOGIES USED IN SMART FARMING

Global Positioning System (GPS)

With pinpoint accuracy, GPS records elevation, longitude, and latitude [32]. By relaying signals from orbit, Global Positioning System satellites enable GPS receivers to calculate their position in real-time and offer continuous positions even when in motion. Farmers may learn exactly where field data, such insect incidence, soil type, weeds, and other obstacles, are thanks to the accurate location information. The technology makes it easy to identify different fields' positions so that inputs like water, seed, fertilizer, herbicide, and insecticide may be applied to each one individually [33].

Sensor Technologies

To assess factors like soil structure and texture, nutrient levels, vegetation, humidity, vapour, air, temperature, etc., methods like photoelectricity, electromagnetics, conductivity, and ultrasound are employed. The use of remote sensing technology has several applications in agriculture, including the classification of weeds and pests, the identification of soil and plant stress points, and the monitoring of drought [34]. There are a lot of variables that might affect a plant's health, including soil moisture, nutrient availability, light, humidity, rainfall, leaf color, and so on. Through micro-irrigation, we can keep the plants at the ideal temperature and light intensity while simultaneously reducing our water and energy use. Many parameters can be detected using various sensors. The sensor will send a signal to the microcontroller to take the necessary steps until the parameter reaches its ideal value if it detects changes that beyond a certain threshold [1]. Sensing technologies typically make use of sensors for measuring things like airflow, temperature, humidity, soil pattern monitoring, location, CO2, pressure, light, and wetness. Sensors are well-suited to the agricultural sector because to their prominent features, which include dependability, memory, mobility, longevity, coverage, and computational efficiency [35]. Data on crop conditions and other information is greatly enhanced by the currently available wireless sensors. You can find these sensors on their own or combine them with high-tech farming implements and heavy machines to meet your specific needs. You can see the many kinds of sensors and how they work and what they're used for in Table 1.

The Use of Grid Soil Sampling with Variable-Rate Technology (VRT)

In agriculture, variable-rate technologies (VRT) are employed to forecast the input delivery rate using a previously established map that has been extrapolated using geographic information systems (GIS). This allows for the precise and timely distribution of inputs in varying amounts and locations [16,33]. In order to create a map for each attribute, grid soil sampling involves collecting dirt from a methodical grid. A variable-rate applicator is fed these maps, which form the backbone of VRT. Modifications to the quantity or type of fertilizer delivered are guided and controlled by the computer and GPS receiver using map characteristics [58,59]. Soil fertility management and the assessment of nutrient and yield spatial distribution can both be enhanced by new technologies like variable rate technology and related practices, such as grid soil sampling [60]. Grid sampling involves superimposing grid lines over a field to divide it into smaller portions, or cells, and then collecting samples from those cells. At the points where the grid lines meet, composite samples capture the whole area, as opposed to grid-point sampling, which only captures a smaller area. Interpolating algorithms are used to map the soil-test values from grid sampling from non-measured sites to the spots that were sampled. Improve nutrient management procedures through uniform applications of fertilizers and manure for improved precision agriculture [61]. Since phosphorus and potassium variability is field-specific, each field should be fertilized individually.

Geographic Information System (GIS)

The geographic information system (GIS) is a collection of interconnected computer programs and hardware that may be used to create maps, analyze locations and features using statistical and spatial methods, and store and retrieve data with various qualities [62]. In addition to detailing the topography, soil type, nutrient status, irrigation, surface and subsurface drainage, chemical application quantity, crop output, and relationships between these factors, the GIS database also includes information on irrigation methods, surface and subsurface drainage, crop production, and chemical applications [63]. The GIS's many uses extend beyond simple data storage and visualization to include evaluating current and potential future management strategies through the creation and manipulation of data layers.

Crop Management

A field's topography can have an impact on crop yields, and satellite photos can show you how the soil is changing over time. Soil, fertilizer, and pesticide inputs are precisely trackable by farmers, allowing them to maximize efficiency and productivity. Satellite imagery provides the data in near real-time on a regional scale due to its extensive coverage area and high revisit frequency over time. Spectral reflectance characteristics of vegetation, particularly in red and near-infrared combinations (vegetation indices) to track green foliage, can be used to forecast the link between crop spectral qualities and their biomass/yield trials [64]. Because of its strong relationship to the leaf area index (LAI) and photosynthetic activity of green vegetation, the normalized difference vegetation index (NDVI) is the most preferred indicator for assessing vegetation health and agricultural output among the many indices [25]. By comparing the current crop state to that of prior or typical seasons, markers acquired from remote sensing can be used to understand the results of crop monitoring systems [65]. During specific times leading up to harvest, one can estimate crop yields using vegetation indices and biomass [66]. The more advanced features offered by automated field management include data acquisition, processing, monitoring, decision-making, and management of agricultural operations [67]. These features encompass the fundamental functions of crop production (yields), financial gains and losses, forecasting farm weather, field mapping, and soil nutrient tracking.

Soil and Plant Sensors

Precision agriculture relies heavily on sensor technology, which provides data on soil qualities, fertility, and water status. This led to the development of new sensors that stand out from the crowd by including desirable qualities [68].

In order to improve crop development conditions, combat biotic and abiotic challenges, and raise harvest yields, plant wearables and soil sensors track physical and chemical data in soil in realtime, including moisture, pH, temperature, and contaminants. The four most crucial minerals for crop productivity are soil organic materials (SOMs), nitrogen (N), phosphorus (P), and potassium (K). Sensors that rely on near-infrared reflectance can track the changes in surface and subsurface soil nitrogen levels across space and time [69]. Optimal wavelengths for predicting SOM are determined by measuring soil spectral reflectance in the infrared and visible light wavelength ranges [70]. The use of near-infrared spectrophotometry allows for the prediction of soil phosphorus and nitrogen levels [71-73]. Because ECa is very sensitive to variations in soil salinity and texture, sensors measuring soil apparent electrical conductivity (ECa) gather data continuously on the field surface. Optioelectronic, acoustic, impedance, and nanostructured biosensors are utilized for the detection of soil insects and pests [74].

Rate Controllers Rate

By tracking the velocities of the vehicles traversing the field, controllers can adjust the material flow rate in real-time to meet the desired rate of input supply. One typical application for rate controllers is as standalone systems [75].. Due of its sensitivity to changes in soil texture and salinity, electrical conductivity (ECa) sensors gather data continually on the field surface. Optioelectronic, acoustic, impedance, and nanostructured biosensors are utilized for the detection of soil insects and pests [74].

Precision Irrigation in Pressurized Systems

Irrigation machines that are dedicated to motion control, use GPS-based controllers, sensor technologies, and wireless communication to track weather and soil conditions while also evaluating irrigation parameters (such as flow and pressure) to achieve more efficient water usage by crops are recent innovations in irrigation systems. Though promising, these technologies still have a ways to go before they can hit the market [76].

Yield Monitor

Sensors, a data storage device, a computer, and a user interface are all parts of a yield monitor, which controls the integration and interaction parts. The sensor examines the volume of grain flow or the force of mass to continually monitor yield. The primary idea behind the mass flow sensor was to send out microwave beams of energy and then measure the amount of energy that reflected back. Using location-based yield data, GPS receivers in yield monitors generate yield maps [77]. Attached to a harvester, the yield monitor communicates with a mobile app that displays data in real-time and uploads it automatically to a web-based platform. In addition to allowing farmers to export data related to farm management for analysis, the app has the capability to create and share high-quality yield maps with agronomists. Fruit growth is one of the most important indicators in the crop advancing phase for horticulture crops to accurately evaluate the yield amount and quality of produce [78]. In order to estimate fruit ripening, make harvesting decisions, and target the correct market, color images are utilized to monitor fruit conditions [79]. Sentinel-1A photos are utilized to map the rice production and crop intensity in Myanmar [80], for example, and they are one option for real-time monitoring of crop yield over wide areas. A combination of software and hardware components was used to build the system for estimating agricultural yields. The app uses a mathematical computation to estimate crop yield, and it's based on an android app and a Bluetooth terminal [81]. Crop yield estimates using spectral fingerprints from space show that the predicted yields are just as accurate as the real ones. Using machine learning and integration of data from satellites into crop models, the maize yield estimates were carried out successfully under different environmental conditions [82].

Software

The software performs a wide variety of operations, including mapping, data processing, analysis, interpretation, display controller interfacing, and more. Maps of soil characteristics and nutrient status, yield, input variable rate applications, and the ability to overlay various types of maps with advanced geostatistical features are typically generated by software [83].

APPLICATIONS IN AGRICULTURE

All of the flaws in traditional agricultural methods can be fixed by using modern sensor and Internet of Things technologies in farming. Smart farming, which makes use of wireless sensors and the Internet of Things, provides solutions to many problems that plague traditional farming methods. These include, but are not limited to, challenges with land suitability, drought monitoring, irrigation, insect management, and yield maximization. The sequence of the primary smart agriculture applications, facilities, and devices is illustrated in Figure 5. The following few cases show how the use of sophisticated technologies at different stages can transform agriculture by increasing efficiency.

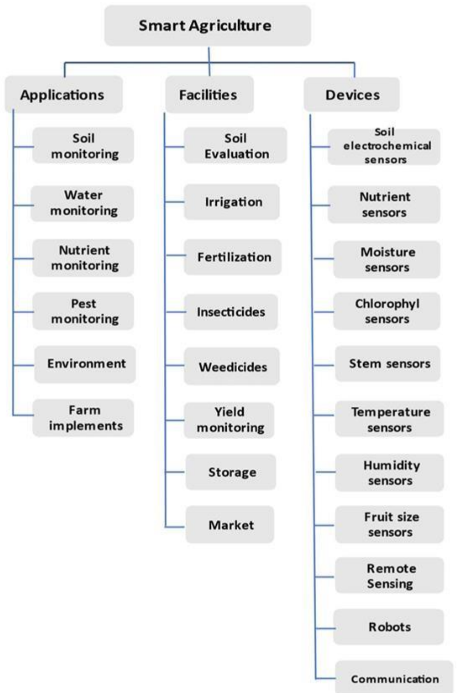

Figure 5. Hierarchy of probable applications, facilities and devices for smart agriculture

Soil Mapping and Plant Monitoring

Based on GPS coordinates and field-specific data, soil analysis can determine the field's nutrient status; crucial decisions are subsequently made in response to nutrient deficits detected at various stages of the crop. Topography, soil type and texture, cropping pattern, fertilizer application, irrigation, and other factors all influence soil fertility status [84]. In order to make the most efficient use of available resources, soil mapping is helpful for determining which crops would do best in a given field, as well as for determining the optimal planting depth and other physical, chemical, and biological soil characteristics. These days, farmers can keep tabs on soil quality and take appropriate measures to prevent erosion, acidification, salinization, erosion, and pollution by using a variety of sensors and tools that measure soil properties like water-holding capacity, texture, and absorption rate. Another issue that impacts plant production and agricultural yield is drought. When it comes to assessing agricultural drought in remote places, remote sensing systems that can gather soil moisture data are a huge help. Estimating the soil water deficit index (SWDI) using soil moisture maps created from satellite data allows for the building of prediction models based on soil physical parameters [85,86]. Soil type, soil nutrients, irrigation, and pests are some of the many elements that impact the yield and quality of rice. The mobile app, which is built on the internet of things, helps with crop management and gives you data about the soil's nutrition and properties in real time. The system is comprised of temperature sensors, an electrical conductivity (EC) meter, a T-Beam microprocessor, and Internet of Things (IoT) connectivity. Around the calibration solution, the estimated EC value is 12.88 mS/cm, and 150 mS/cm is less than 2% of that value. At 5 cm depth, the measured EC values were 1.04 and 3.86 mS/cm, respectively, with and without fertilizer; at 10 cm depth, the values were 0.656 and 420 mS/cm, respectively, and they are directly related to both depth and temperature [87]. Improving grape productivity and crop quality from seeding to harvest is possible with the help of data collected by sensors and mobile devices (smartphones and tablets) through an Internet of Things (IoT) ADCON-based station that monitors plants. This data includes soil and ambient parameters like leaf wetness, air and soil temperature, soil and air humidity. In addition, the data transmission system emphasizes the interplay between soil, plants, and the environment, which is crucial for maximising crop yields [88]. The data was analyzed by comparing the readings from the light, temperature, soil moisture, and carbon dioxide sensors in bell peppers that were grown in a greenhouse. The peppers were then subjected to day and night CO2, and the greenhouse's doors and windows were opened and closed depending on the soil moisture [89].

Irrigation

The United Nations Convention to Combat Desertification (UNCCD) estimates that 168 nations would be severely affected by desertification by 2030, and that approximately half of the global population resides in regions with severe water scarcity [90]. Regions need to be supplied with water quantities due to the water problems and the increased need for agricultural and other activities. More efficient and controlled irrigation techniques, such as drip and sprinkler irrigation, are being used to conserve water supplies. Factors such as soil type, precipitation, irrigation method, crop type, requirement, and soil moisture retention control the estimation of water demand for crops. Water resources can be better utilized and crop health can be enhanced through the use of wireless sensor systems for air and soil moisture control. Using Internet of Things (IoT) methods, including crop water stress index (CWSI)-based water management [91], which is determined from the crop canopy at different phases of crop growth and air temperatures, is expected to significantly enhance crop yield in the current context. The CWSI model uses data from sensors, weather stations, and satellite images to determine how much water each field needs. Then, depending on the field's slope or soil variability, irrigation index values are utilized to make forecasts about how much water to use.

Site-Specific Nutrient Management

Fertilizer is a chemical compound, either naturally occurring or artificially produced, that increases soil fertility and plant development. Damage to soil, plant health, and the environment can result from either nitrogen deficiency or excessive fertilizer application [92]. Smart agriculture practices, such as site-specific soil nitrogen fertilization, precisely estimate nutrient needs while minimizing their harmful impacts on soil and the environment. Soil types, crop types, production targets, exchange capacity, use efficiency, fertilizer types, weather conditions, and other factors all impact the site-specific soil nutrient readings. Estimates of the nutrient's geographical patterns of dispersion are provided by the IoT-based fertilization technique [93,94]. Soil nutrient level, crop health, vegetation vigor, plant density, and the normalized difference vegetation index (NDVI) were all assessed using satellite pictures [95,96]. Smart fertilization based on the Internet of Things is greatly enhanced by recent technologies such as global positioning systems (GPS) [97], geographic mapping (GM), variable rate technology (VRT) [99,100], and autonomous vehicles [101]. Other effective management strategies to boost fertilization efficiency include fertigation [102] and chemigation [103,104], which involve using water-soluble fertilizers as soil amendments and insecticides.

CONCLUSION

In order to meet the growing global need for food while also preserving the diminishing amount of arable land, more innovative and effective approaches to crop production are required. Everyone must be cognizant of the need of food security in relation to environmentally responsible farming. Innovation in agricultural technology is driving up crop yields and attracting creative youth to the field as a respectable career path. In order to make agriculture smarter and more successful in fulfilling future requirements, this study highlighted the role of numerous technologies utilized for farming, including the IoT. For the benefit of academics and engineers, we have highlighted the present difficulties and potential future developments in the industry. As a result, sustainable Internet of Things (IoT) sensors and communication technologies should be used to every inch of farmland in order to increase crop yield.

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