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Innovative Technologies in Agriculture: Leveraging AI, ML, and IoT for Sustainable Food Production and Resource Management

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This review explores the integration of artificial intelligence (AI) and machine learning (ML) in agriculture, emphasizing their role in enhancing crop yield through improved seed selection and waste reduction. AI and ML facilitate the identification of favorable genes and the classification of crop products, aiding farmers globally. Despite these advancements, modern agriculture faces challenges related to energy consumption and the adoption of Internet of Things (IoT) technologies. High energy demands for sensor deployment and data transmission, along with the costly adoption of renewable energy, hinder progress. However, the adoption of smart grids and microgrids, along with advancements in energy storage solutions, offer potential solutions. Vertical farming and hydroponic systems emerge as crucial methods to address land scarcity and water shortages, particularly in urban settings. As the global population grows and urban areas expand, these technologies are vital for sustainable food production. The review underscores the need for modern technology, including IoT, cloud computing, remote sensors, and unmanned aerial vehicles, to advance agricultural practices. Embracing these technologies will enhance resource efficiency and support the transition to sustainable agriculture, addressing the pressing challenges of modern food production.

Keywords: Internet of Things (IoT), Unmanned Aerial Vehicles (UAVs), Sustainable Agriculture, and Agricultural Advancements.

Introduction:

Sustainable agriculture refers to the endurance and maintenance of food production in an environmentally friendly manner [1]. It promotes farming practices that support farmers and conserve resources. This approach is economically viable, enhances soil quality, reduces degradation, conserves water, improves land biodiversity, and ensures a natural and healthy environment [2]. Furthermore, sustainable agriculture plays a crucial role in preserving natural resources, preventing biodiversity loss, and reducing greenhouse gas emissions [3].

Sustainable farming methods aim to protect nature while meeting the needs of future generations and improving farming efficiency. Key practices include crop rotation, nutrient management, pest and disease control, recycling, and water harvesting, all contributing to a safer environment. Biodiversity is essential for life, but it is threatened by waste emissions, fertilizers, pesticides, and degraded plant material. Greenhouse gas emissions affect plants, animals, humans, and the environment, highlighting the need for a healthier environment for all living things [4]. Agriculture is India's largest industry, contributing 18% to the gross domestic product and involving about 57% of the rural population. Despite an increase in agricultural output, the number of farmers decreased from 71.9% in 1951 to 45.1% in 2011 [5]. The 2018 Economic Survey predicted that the agricultural workforce would drop to 25.7% by 2050. Rural farming families are gradually losing future generations of farmers, due to high cultivation costs, low productivity, poor soil maintenance, and migration to more lucrative occupations. As the world undergoes a digital revolution, now is the time to integrate agricultural landscapes with wireless technology, enhancing digital connectivity for farmers.

Unfortunately, not all areas of the Earth are suitable for agriculture due to factors like soil quality, topography, climate, and temperature, with many cultivable areas lacking homogeneity [6]. Existing farmland is further fragmented by political, fiscal factors, and urbanization, increasing pressure on arable land (Figure 2). Recently, there has been a decline in agricultural land used for food production [7]. Each crop field has unique characteristics—such as soil type, irrigation flow, nutrient presence, and pest resistance—that must be measured separately for optimal production. Spatial and temporal variations are essential for optimizing crop production through crop rotation and annual growth cycles [8].

In many cases, variations occur within a single crop or when the same crop is grown across an entire farm, necessitating site-specific analysis for optimal yield. Modern technology is required to maximize output from limited land and address these challenges. Traditionally, farmers frequently visited their fields to monitor crops, but current sensor and communication technologies offer precise, real-time views of the field, enabling farmers to detect issues without being physically present [9]. Wireless sensors monitor crops with high accuracy, allowing for the early detection of problems and the use of smart tools throughout the growing season, from sowing to harvest [10].

The timely use of sensors has made farming operations more efficient and cost-effective through precise monitoring. Various autonomous harvesters, robotic weeders, and drones equipped with sensors collect data at short intervals. However, the vast scale of agriculture places significant demands on technological solutions to ensure sustainability with minimal ecological impact. Sensor technology, through wireless communication, allows farmers to understand their crops' needs and take remote action accordingly [11][12].

Currently, multiple organizations and sectors are creating innovative technologies, such as the Internet of Things, to improve farm management. By reducing the risks that are connected to these technologies, they enable the achievement of the best possible results and advancements in their respective industries. Although farmers have the necessary financial resources to obtain state-of-the-art technology, their ability to obtain information about the Internet of Things is limited [13]. However, the Internet of Things (IoT) is widely regarded as a promising technology for sustainable agriculture and can be easily embraced by farmers to enhance agricultural production. The Internet of Things (IoT) is an example of a new technology that greatly improves important infrastructures. These enhancements involve the use of internet-connected mobile devices and a diverse array of services, such as cloud-based sensor data, automated farming operations, and the ability to make well-informed choices [14][15]. The agriculture business, as the main driver of the economy and the foundation of the nation, will experience a substantial change as a result of the emergence of the Internet of Things (IoT). It will provide information on the main factors that make the employment of this modern technology necessary. Furthermore, it highlights the notable obstacles linked to this technology and its integration in advanced agriculture, including a fragmented market, inadequate connectivity and coverage, investment constraints, a lack of cutting-edge and applicable technology, a shortage of skilled labor, and various other hindrances [16][17].

Scientists, researchers, and engineers are creating many advanced technologies and approaches to track crops and related field data in order to enhance the agriculture industry. We are already receiving queries from multiple manufacturing businesses who are interested in supplying us with a range of tools and technologies, including IoT sensors, robotics, and UAVs. These tools and technologies would enable us to collect data in real time with considerably improved levels of detail. Both governmental and non-governmental organizations are collaborating to improve Internet of Things (IoT) applications with the aim of guaranteeing and safeguarding food security and safety [18].

There are many projects that focus on demonstrating the practical application of the Internet of Things in the agricultural industry. The majority of the previously released data either lacked adequate context or concentrated on different IoT-based designs, prototypes, and enhanced approaches, as well as the usage of IoT for crop data management and monitoring applications and related contexts [19]. These individuals conducted a review of past research on the possible uses of the Internet of Things (IoT) in the area of arable farming. The emphasis was placed on the app, network, and device layers that constitute the architecture of the Internet of Things. Navarro et al. undertook a comprehensive assessment of IoT technologies for smart farming, specifically focusing on the concept, number of publications, and IoT implementations in agriculture. Talavera et al. conducted a study on the global distribution of research related to the Internet of Things (IoT), as well as the application of IoT in energy management, communications, logistics, and monitoring [20].

This review study specifically examined the latest developments in agricultural research that make use of cutting-edge technology, with a specific focus on the uses of IoT (Internet of Things) and UAV (Unmanned Aerial Vehicle). The study also analyzed numerous crucial topics that need to be addressed in order to effectively utilize the potential of the Internet of Things and other modern technologies to revolutionize the agriculture industry [21]. This review provides a precise analysis of several key areas, including the global outlook for agricultural advancements, the technological challenges faced by the agricultural sector, and the importance of major equipment and technologies like IoT and UAVs in addressing these challenges. It also explores their role in addressing concerns such as food quality, environmental pollution, climate change, and resource scarcity, and emphasizes the need for their precise utilization [22]. Showcasing the most recent advancements in the Internet of Things and other technologies that enable sophisticated farming;

Important factors and rules to keep in mind while integrating new technology, like the Internet of Things, with contemporary agricultural methods;

- Primary concerns regarding food safety and corresponding suggested remedies;
- The future prospects and suggestions for this cutting-edge technology.

Evolution of Agricultural Practices: From Traditional Methods to Smart Farming:

Traditional Agriculture 1.0:

Historically, ancient agricultural practices centered around food production in cultivated lands for human survival and animal breeding. This period, often referred to as traditional agriculture 1.0, relied heavily on manual labor and animal power, utilizing simple tools like sickles and shovels. The work was predominantly manual, resulting in low productivity levels.

Agricultural Era 2.0:

The 19th century marked the beginning of agricultural era 2.0 with the advent of steam engines and the introduction of machinery. This era saw increased productivity and effectiveness but also led to significant environmental issues, including chemical pollution, resource depletion, and excessive energy use.

Agricultural Era 3.0:

The 20th century introduced agricultural era 3.0, characterized by rapid advancements in computation and electronics. Innovations such as robotic technologies, programmed machinery, and improved pest control technologies addressed many of the environmental challenges of era 2.0. Precision irrigation, reduced chemical use, and site-specific nutrient application became prominent, enhancing agricultural efficiency.

Agricultural Era 4.0:

Currently, we are in agricultural era 4.0, incorporating cutting-edge technologies such as the Internet of Things (IoT), big data analysis, artificial intelligence, cloud computing, and remote sensing. These advancements have revolutionized agriculture by developing cost-effective sensor and network platforms, optimizing production efficiency, and minimizing water and energy usage with minimal environmental impact. Smart farming, a key aspect of this era, enables remote monitoring and precision agriculture, transforming traditional methods into automated systems.

Smart Farming:

Smart farming integrates information and communication technologies (ICT) to optimize labor requirements and improve both the quantity and quality of agricultural products. Technologies such as IoT, GPS, sensors, robotics, drones, precision equipment, actuators, and data analytics address farmers' needs, enhance decision accuracy, and increase crop productivity [23][24]. Smart agriculture addresses challenges such as changes in soil characteristics, climate factors, and soil moisture to improve spatial management and reduce the overuse of fertilizers and pesticides.

Technological Contributions to Smart Farming:

Various technologies contribute to smart farming, including Global Positioning Systems (GPS) for precise location data, sensor technologies for monitoring soil and plant conditions, and variable-rate technologies (VRT) and grid soil sampling for optimized input delivery. Geographic Information Systems (GIS) offer comprehensive data analysis, while crop management tools utilize satellite images to monitor soil conditions and crop performance. Soil and plant sensors provide real-time data on soil properties and crop health, and precision irrigation systems enhance water efficiency. Yield monitors and software applications support various tasks, advancing modern agriculture [25].

Table 1: the evolution of agricultural practices

Era	Key Characteristics	Technologies and Practices
Traditional Agriculture	Reliance on manual labor, basic tools, and animal power. Limited productivity and efficiency.	Hand tools (e.g., plows, sickles), animal-drawn carts, traditional irrigation techniques
Agricultural Revolution	Introduction of mechanized equipment, leading to increased productivity and efficiency but also causing environmental concerns.	Steam engines, mechanized tractors, early chemical fertilizers and pesticides
Green Revolution	Significant advancements in crop varieties, irrigation methods, and chemical inputs. Increased yields and improved food security.	High-yielding crop varieties, chemical fertilizers, pesticides, modern irrigation systems
Modern Agriculture	Focus on precision farming, use of technology for data-driven decision making, and sustainability. Emphasis on reducing environmental impact.	GPS-guided machinery, drones, sensors, precision irrigation, data analytics, sustainable farming practices
Smart Agriculture	Integration of IoT, AI, and advanced data analytics to optimize farming practices and address challenges such as climate change and resource management.	IoT devices, AI algorithms, remote sensing, big data analytics, automated systems for planting and harvesting

Techniques:

In recent decades, several studies have been carried out to address key agricultural challenges with the goal of improving agricultural productivity and ensuring food security. Many scholars have made substantial efforts to advance agriculture, motivated by recent technological advancements and the potential to utilize these advances to improve agricultural productivity. Science has exhibited an increasing fascination with state-of-the-art technology, including unmanned aerial vehicles (UAVs), wireless sensors, and Internet of Things (IoT) sensors. Nevertheless, the challenge of choosing and implementing the suitable technology to improve crop yield is a complex endeavor for users and stakeholders. Several recent studies have examined the usage, implementation, potential, difficulties, and future prospects of IoT technology in the agroindustry and smart farming sector [26]. Nevertheless, their main emphasis was predominantly on carrying out research that revolved around the Internet of Things (IoT). We extensively examined the majority of significant research that depend on sophisticated technology, which are crucial for progress in agriculture, either individually or in conjunction [27].

We aimed to evaluate publications that specifically focus on cutting-edge technology. The chosen articles primarily addressed the subjects of Internet of Things, smart and precision agriculture, drones and UAVs, wireless communication technologies, and smartphone applications in the agricultural business. Furthermore, there were papers that examined the application of IoT sensors and wireless devices for monitoring several agricultural factors, including crop productivity, climate data, plant diseases, vegetation health, and soil moisture, among others. All the technologically-driven research undertaken in the past two decades that has contributed to the progress of agriculture was encompassed.

Table 2: Summary of Technological Advancements and Applications

Technology/Method	Current Applications	Recent Developments	Future Prospects
Internet of Things (IoT)	Monitoring soil moisture, crop productivity, climate data	Improved sensors, real-time data analytics	Enhanced precision and automation, broader adoption
Drones and UAVs	Aerial monitoring, crop health assessment, precision spraying	Advanced imaging, better integration with other tech	Increased use in precision agriculture, real-time feedback
Wireless Sensors	Soil moisture monitoring, climate data collection, pest detection	Integration with IoT, enhanced sensor accuracy	More detailed and localized data, wider deployment
Smartphone Applications	Data collection, remote monitoring, management tools	Enhanced features, improved user interfaces	Greater integration with other technologies, personalized management
Robotic Machinery	Automated sowing, weeding, fertilizing, and harvesting	Development of Agri bots and Farm bots	Increased efficiency, reduced labor costs
Soil Monitoring Technologies	Soil nutrient analysis, moisture level monitoring	Innovations like Scanner and Lab-in-box	More frequent and detailed analysis, better field-specific solutions

Technology/Method	Current Applications	Recent Developments	Future Prospects
Irrigation Systems	Drip and sprinkler systems, water management	Intelligent irrigation, real-time moisture monitoring	More efficient water use, integration with IoT for precise irrigation

Essential Services and Applications in the Agricultural Sector:

Modern technologies like the Internet of Things and unmanned aerial vehicles (UAVs) have completely transformed and combined all of the conventional methods. At now, the utilization of several wireless and Internet of Things sensors offers numerous prospects for progress in agriculture. Currently, these developing technologies are addressing a range of conventional crop challenges, such as disease management, efficient irrigation, cultural practices, and drought responses [28]. Illustrates the hierarchical arrangement of services, wireless sensors, and core applications for sophisticated agricultural objectives. This section examines cutting-edge technology used to monitor vital applications in order to improve agricultural productivity.

Soil Monitoring:

Soil is essential for the proliferation and maturation of plants. It is essential to monitor soil conditions at the level of individual fields. At various stages of plant development, a farmer can make educated evaluations by gaining knowledge about the soil's condition. The primary goal of soil analysis is to quantify the amount of nutrients in the soil, which then informs various actions aimed at restoring the optimum nutrient levels. It is highly recommended to conduct a soil test every year in the spring. However, it can also be conducted in the winter or autumn, depending on the current environmental conditions in the area. It is advisable to evaluate multiple soil parameters, including soil types and soil moisture levels, to ascertain the need for fertilizers and irrigation [29]. These fundamental traits also aid in acquiring information about other significant elements, such as the physical, chemical, and biological factors. The soil map aids in locating locations with favorable soil health and texture for optimal seed compatibility, sowing timing, and sowing depth, by considering the diverse root depths of various plant species.

In recent times, numerous researchers have devised methodologies, technologies, and devices to evaluate the condition of soil. These newly developed technologies are essential assets for farmers and producers to oversee soil characteristics, including moisture content, water retention capacity, and chemical and physical properties. These sensors have the ability to monitor the condition of the soil and help determine the appropriate quantity of fertilizer needed by detecting several factors such as salinity, pH, electrical conductivity (EC), soil organic carbon (SOC), nitrogen, potassium, and phosphorus [30]. The Scanner and Lab-in-box, referred to as an all-encompassing information laboratory, is a recent technical innovation created by Agro Cares that provides soil condition data. Many farmers without access to a laboratory for sample analysis utilize this customized gadget. This machine has the capability to analyze around 100 soil samples per day.

Regularly monitoring soil moisture levels is a vital challenge in determining the water requirements of crops. Using in situ soil moisture monitors, remote sensors, and tools can be effective approaches for monitoring soil moisture levels on many farms. Several satellites are now being used to collect worldwide soil moisture data. The remote sensing products now offered are: (i) AMSR2, which has been in operation since 2012; (ii) SMOS, which has been in operation since 2010; (iii) AMSR-E, which was operational from 2002 until September 2011; and (iv) SMAP, which has been in operation since 2015. The Soil Moisture and Ocean Salinity (SMOS) effort, which began in 2009, started its worldwide monitoring of soil moisture in May 2010. Furthermore, wireless in situ soil moisture sensors provide the potential to monitor and quantify soil moisture levels in agricultural fields.

Novel technologies are employed to evaluate crop characteristics, such as the depth of the soil, in order to optimize the process of planting seeds. These are sensors that rely on visual input and wireless communication. Agri bots and Farm Bots are two categories of robotic machinery currently under development for the purpose of smart farming, with the aim of improving crop yield. The extensive adoption of these technologies in agricultural processes, including sowing, weeding, fertilizing, and irrigating, would lead to a substantial increase in crop yield. Agri bots are a specialized category of robots that utilize digital computers and the optical system of the vehicle to accurately ascertain the location of the agricultural area. This particular type of robot is suitable for deployment on agricultural properties that utilize the global positioning system (GPS) to generate location maps. LED-mounted sensors facilitate the accurate measurement of seed flow rate. In order to accomplish this, a wide array of remote sensors are employed. The LEDs serve as the origin of radiation, emitting wavelengths of both infrared and visible light. Multiple components, such as the voltage output, receiving element, and light band, are utilized to monitor the movement of the seed. Seed transfer facilitates the linkage of signals to quantify the rate at which seeds move. Soil analysis is commonly conducted using sophisticated technologies and devices, which also aid in monitoring the growth and productivity of crops. Irrigation refers to the artificial application of water to land or crops in order to promote their growth and productivity [31].

The Earth's oceans hold around 97% of its water, with salinity being a defining characteristic. Of the entire amount, merely three percent is comprised of freshwater, with approximately two to three percent being in the form of glaciers. Of the entire quantity of freshwater, which constitutes three percent, half is in the form of surface water, while the other half is groundwater. Humans require only 0.5 percent of freshwater for their life. The 0.5 percent of freshwater comprises the water contained in lakes, rivers, and other reservoirs. Around 75% of the Earth's freshwater resources are designated for agricultural use. The crop demand in many nations, particularly Brazil, has experienced a significant increase of 75%. The main reason for the irregular use of irrigation water is a range of constraints, including the absence of appropriate monitoring systems to precisely evaluate the water requirements of crops. As an illustration, irrigation accounts for over 80% of the overall freshwater usage in the United States [24]. During the 2013 United Nations Convention to Combat Desertification (UNCCD), it was disclosed that more than 168 countries worldwide experience inadequate water supplies for agricultural use. Studies predict that by 2030, there will be a substantial global deficit of water specifically intended for agriculture.

Only nations that have effectively implemented advanced water resource management techniques will be capable of obtaining fresh water, given the rising demand for agricultural water. In order to alleviate water scarcity, it is crucial to allocate funds for awareness efforts that promote the adoption of efficient irrigation techniques. To minimize losses and tackle water scarcity, several innovative irrigation techniques are employed, including drip and sprinkler systems. Water is wasted by traditional methods such as flood irrigation and furrow irrigation. Moreover, the utilization of traditional irrigation methods, such as flooding, causes water wastage, leading to a reduction in soil nutrients and thus affecting crop productivity. Robust technology and advanced instruments, particularly intelligent irrigation methods, are indispensable. Intelligent irrigation systems may utilize several criteria, including soil types, current soil moisture levels, and climate conditions, to accurately determine the water needs of crops. Contemporary technology, like the Internet of Things, greatly aids in assessing soil and air humidity, consequently improving the quality of crops.

Effective management of soil and water resources can lead to improvements in crop quality. The application of IoT, namely for regulating irrigation based on the crop water stress index (CWSI), is anticipated to greatly improve agricultural productivity. It is crucial to acquire a crop canopy under various time and temperature conditions in order to calculate the Crop Water Stress Index (CWSI) [23]. The amount of water needed for irrigation can be estimated by evaluating the moisture level using several crop parameters measuring devices that are part of a wireless sensor-based monitoring system called CWSI.

Plant Pathology and its Control:

Phytophthora infestans caused the late blight disease in potatoes in Ireland, resulting in a famine and significant loss to crops. Around one million people died as a consequence of this famine in Ireland. The occurrence of southern corn leaf blight in the United States, triggered by the fungus Cochliobolus heterostrophus, resulted in substantial agricultural damages totaling around $1 billion USD and played a role in the prevalence of hunger. This crop disease eventually extended to Canada. According to the Food and Agriculture Organization (FAO), crop diseases result in an annual global crop loss ranging from 20% to 40%. To mitigate these losses, several agricultural management measures were implemented, including the use of insecticides and fungicides. These strategies have been utilized in complex agricultural practices since the start of the 21st century. The United States alone utilizes over 500,000 tons of insecticides annually. In contrast, certain nations employ a staggering two million tons of pesticides annually for the purpose of disease management. While pesticides are used to control plant diseases and improve agricultural productivity, they have numerous adverse effects on the health of both humans and animals. In the end, it greatly pollutes the entire environment due to its disturbance of the global ecology.

The use of these dangerous compounds is mostly being reduced thanks to advanced technology like the Internet of Things. These sophisticated and developing agricultural technologies manage various crop disease monitoring systems, including crop modeling, pest prediction, and weather forecasting. These technologies are regarded as efficient methods for tackling crop and plant diseases. Emerging technologies, such as the Internet of Things, wireless sensors, and unmanned aerial vehicles, are crucial in the diagnosis of illnesses and the management of pests. However, the efficacy of disease forecasting, monitoring, and management is dependent on the administration of medication, the perception of the disease, and the evaluation of its severity. For instance, it is economically viable to acquire extensive agricultural land by applying remote sensing technologies [32]. Remote sensors can be employed to evaluate several elements of crop processing, including disease and pests, plant health, and the environment. This cost-efficient remote sensing device offers various benefits, including economical automated activation and recovery assistance. Lately, the inadequate process of pollination has posed a substantial risk to the productivity of many crops.

Apply Fertilizer:

Plants mainly obtain the vital nutrients required for their growth, development, and reproduction from fertilizers or organic amendments. The growth and development of the flower, fruit, and root necessitate three vital nutrients: nitrogen for leaf growth, phosphorus for root development, and potassium for stem expansion and water movement throughout the plant. The uneven allocation of these nutrients across the plant can impact the plant's overall health. The overuse of these nutrients and fertilizers has a harmful effect on the plant's health and has bad consequences for both the plant and the environment, such as damaging the quality of soil, water, and air. For instance, only 50% of the total nitrogen is utilized for crop growth, while the remaining 50% is discharged into the environment [33]. The climate and ecosystem have detrimental consequences as a result of the uneven allocation of excessive nutrients to the crops. Furthermore, it improves the nutrient composition of the soil. Smart agriculture employs cutting-edge technologies, such as the Internet of Things, to precisely determine the optimal quantity of fertilizer required. Furthermore, these methods effectively mitigate the adverse effects on the environment.

Advanced technology enables the estimation of nutrient administration in a spatial-temporal manner, specifically for fertilization purposes. This method is characterized by reduced labor requirements and a focus on optimizing productivity. The normalized vegetation index (NDVI) is frequently used to assess the health of plants, making it easier to anticipate the best time to apply soil fertilizer [34]. Utilizing effective solutions can optimize the efficiency of nutrient application, while minimizing its environmental impact. The capacity to assess nutrients in the field is enhanced by several sophisticated technologies, including global positioning systems (GPS), variable rate technology, and geographic information systems (GIS). Using fertilizers is the most effective way to improve agricultural productivity, and applying modern tools and technology, such as the Internet of Things, is the only way to start producing them.

Monitoring and Predicting Crop Harvests:

The yield monitoring system tracks and analyzes the moisture content, grain mass flow, crop yield, and grain quantity per crop. Verifying the crop yield and moisture content is essential for appropriately assessing the overall crop performance. Monitoring crops is an essential task that must be carried out during the growing season. Precise crop production measures are crucial during both the maturation period and various developmental stages of the crop. Crop production monitoring involves several components, such as achieving ideal pollination rates, especially considering environmental variations and the requirement for precise seed prediction.

Crop forecasting refers to the process of anticipating crop yields prior to harvest. Agricultural practitioners can use these forecasts to aid in the development and implementation of prompt strategies and decisions. Furthermore, the evaluation of crop maturity and quality can be employed to precisely ascertain the ideal moment for harvesting [35]. During the monitoring procedure, one can evaluate many characteristics of fruits, such as their color, size, quality, and developmental stages. Precise crop forecasting can improve approaches to controlling agricultural illnesses, as well as maximize crop yield and quality at different stages of growth. Hence, having knowledge about the ideal time for harvesting is essential for improving the quality of crops. Illustrates a standard screenshot of the farm area network (FAN), which provides farmers with real-time visual representation of their whole property.

Any harvesting machine has the capability to be connected to a cutting-edge technology, such as a highly advanced yield monitor. The Farm RTX mobile application enables users to retrieve accurate harvesting data by establishing a connection with the yield monitor tool. Finally, the data is examined and sent to the manufacturer's online application [36]. This mobile application allows users to create precise mapping tools and share them with professionals and farmers to be included into other agricultural devices, making it easier to monitor crop yield.

Communication Related to Agriculture:

Prompt and accurate information reporting and communication are regarded as the essential components of sophisticated agriculture. To achieve effective and meaningful goals, multiple elements must be intricately integrated and actively engaged. Telecommunication operators are crucial in improving the dependability of communication for the advancement of agriculture. Furthermore, the implementation of a highly effective managerial system is vital for enhancing the Internet of Things and total knowledge, thereby bolstering the sophisticated agricultural business. Prior to choosing a communication method, it is essential to consider various important variables such as coverage, energy efficiency, reliability, and cost. Wireless communication refers to the transmission of information or data without the need of physical wires or cables.

Switching from a 2G to a 5G cellular connection method may be suitable, depending on the particular application and bandwidth needs. Moreover, the availability and dependability of cellular networks are crucial considerations in rural areas. Using satellite communication is a practical approach for dealing with this significant problem. However, the use of this communication technology can result in high costs, making it impracticable for small and medium-sized farms. The choice of the communication model is additionally determined by the application's requirements. For instance, several farms employ sensors that must function at a low data rate while also ensuring a long lifespan and extended battery longevity. The introduction of the new low-power wide area network (LPWAN) series is anticipated to greatly enhance the performance of cellular networks in this scenario. LPWAN provides a greater cost-effectiveness, with rates varying between 2 and 15 USD. Additionally, it has an expanded connectivity range and boasts an extended battery lifespan. LPWAN networks are now most advantageous for two main agricultural applications: crop management and pasture management. These networks can be used for several additional agricultural applications because of their impressive accomplishments. Wireless sensors used in agriculture are often categorized into three primary classes based on the rate of data transmission and energy usage.

Bluetooth:

Bluetooth is a crucial means of communication used to establish wireless connections over short distances between small devices. Various agricultural devices in the Internet of Things (IoT) category are equipped with Bluetooth functionality, such as the FarmNote Air gateway and Color sensor. Bluetooth is currently being studied as a viable tool for multi-tier agricultural operations due to its widespread use.

Zigbee:

Zigbee was originally created to replace non-standard equipment, however it can also be used in various other fields. Devices that comply with this code of conduct can be categorized into three groups: coordinator, end-devices, or router, depending on the unique requirements of the application. Furthermore, Zigbee networks can be employed with three distinct topologies: Mesh, Star, and Cluster Tree. Given these characteristics and the specialized requirements of agricultural applications, ZigBee can play a key role, especially in greenhouse settings where there is a frequent need for communication across short distances. Zigbee is employed for transferring real-time data from the sensor nodes to the terminal server during various parameter observations. The ZigBee module can be employed for transmission purposes, specifically in drip irrigation systems, to monitor the soil's moisture level in applications such as fertilizers and irrigation.

Sensory equipment encompasses gadgets or tools specifically created to excite or augment the senses, including touch, sight, hearing, taste, or smell. Sensor devices play a vital role in contemporary and advanced agriculture. They have a vital function in gathering data on the state of crops and other pertinent topics. Sensor devices can be employed either individually or together, as required. Furthermore, sensor devices are employed in intricate agricultural practices due to their sophisticated technology. Subsequently, the conversation centers on the operation, function, and advantages of the primary categories of sensors. Here is a collection of the main sensors used in advanced agricultural techniques [37]. The device's operational state enables the collection of precise information, including data on geographical areas and locations, as well as aiding in the identification of travel routes. These programs aid agricultural managers by automatically storing and documenting data associated with agriculture.

Remote sensing technologies are employed to collect and archive diverse environmental and climatic indicators, together with geographic data. Moreover, it facilitates the administration, modification, depiction, and assessment of spatial and geographic data. These sensors aid in assessing several elements such as land degradation, yield estimation, crop evaluation, prediction, monitoring, and pest management. They employ advanced technology such as LiDAR, satellite images, and unmanned aerial vehicles (UAVs). For instance, the Argos sensor can be utilized with smartphone platforms to analyze, distribute, and gather data on a worldwide scale.

Cutting-Edge Technology for Enhancing Agriculture:

With the progression of technology, the majority of manufacturers are outfitting their tractors with automated drives. Since self-driving tractors were already available in the market prior to semi-autonomous cars, this equipment cannot be deemed as very sophisticated. One major advantage of self-driving tractors is their ability to reduce overlaps to less than an inch, thus preventing them from reentering the same area or row. Furthermore, they possess the ability to perform exceptionally precise turns autonomously, eliminating the requirement for a human driver. The device attains greater precision and minimizes mistakes, particularly when applying pesticides or targeting weeds, activities that are virtually unfeasible to carry out with a human operator. Although there are now no fully automated tractors or machinery available for purchase, a significant number of scientists, researchers, and manufacturers are actively working towards the development of this innovative technology [38]. By 2028, it is estimated that around 700,000 sophisticated tractors with automated steering and tractor guiding capabilities would be commercially accessible. This is in response to the increasing demand for technologically improved tractors. Furthermore, it is estimated that by the year 2038, a grand total of 40,000 fully autonomous (level 5) automobiles and tractors would be acquired.

Nevertheless, the bulk of tractor manufacturers and service providers deliver below-average performance, resulting in a lack of accessibility for most farmers to acquire technologically updated farming equipment. As an illustration, Hello Tractor has devised a method to tackle these issues in response to these challenges. The company has created an affordable tracking device equipped with sophisticated software and advanced analysis capabilities, which can be effortlessly placed on any tractor. This gadget has two benefits: it checks the condition of the tractor and rapidly alerts any issues that may arise, so ensuring that most farmers can effectively control the overall expenses of the tractor [39]. Similar to Uber's automobiles, the software links tractor owners with farmers who need tractor services. The Magnum series tractors manufactured by Case IH serve as another notable example. These tractors utilize light detection and ranging (LiDAR) sensors and on-board cameras to detect objects, thereby reducing collisions and effectively handling mishaps caused by agricultural machinery.

Cloud-based software refers to software that is accessible and utilized through the internet, as opposed to being installed on a computer or server located locally. Growers can leverage cloud services to access data from predictive analytics companies, enabling them to identify and acquire goods that are specifically matched to their unique needs. Cloud computing allows farmers to access a rich repository of knowledge containing practical counsel and insights on various farming techniques and equipment choices. To increase the program's dynamism, it can be expanded to incorporate integration with customer databases, supplier networks, and invoicing systems.

Cloud-based services have various potential and unique obstacles. At first, a wide variety of sensors, each with its own unique data format and significance, are being created and used in the field of smart farming. Moreover, a substantial fraction of Decision Support Systems (DSSs) is explicitly tailored for a certain objective. However, farmers may require access to different systems for certain purposes, such as soil monitoring. In light of these two scenarios, it is crucial for cloud-based decision support systems to possess the flexibility to generate unique formats for different applications, while also efficiently managing a diverse array of data types and formats.

Current Progress and Future Prospects of Agricultural Technology

Agricultural technology (AgTech) is advancing at a remarkable pace, playing an essential role in promoting sustainable agriculture. One of the significant advancements in this field is precision agriculture, where AI, GPS, and sensors are used for precise monitoring and management of crops. This technological approach minimizes resource usage and maximizes yields, with companies like Taranis leading innovations in AI-driven field monitoring. Another key area of progress is the growing importance of robotics in agriculture. Farm robots are increasingly being utilized for tasks such as planting, weeding, and harvesting. The global market for agricultural robots was valued at $7 billion in 2022 and is projected to reach $24 billion by

2030, highlighting the strong growth in this sector.

Biodegradable innovations are also emerging as vital tools in reducing the environmental impact of farming practices. Researchers are developing biodegradable polymer coatings and sustainable alternatives to traditional processes, such as the Haber-Bosch process. Genetic engineering is another area where significant advancements are being made, particularly with the development of synthetic promoters that enhance the efficiency and resilience of crops, thereby contributing to sustainable food production. Additionally, smart filters and advanced water management systems are being developed to address issues like pesticide contamination, further enhancing the sustainability of agriculture.

Looking ahead, the future of AgTech appears promising, with expectations of increased adoption of AI and robotics driven by the need for precision and efficiency in farming. The development of sustainable fertilizers and biodegradable materials is likely to play a crucial role in reducing agriculture's environmental footprint. Moreover, genetic advancements will continue to focus on improving crop resilience, enabling better adaptation to climate change and other environmental stresses. These ongoing developments in AgTech promise to transform agriculture into a more sustainable and resilient industry [40].

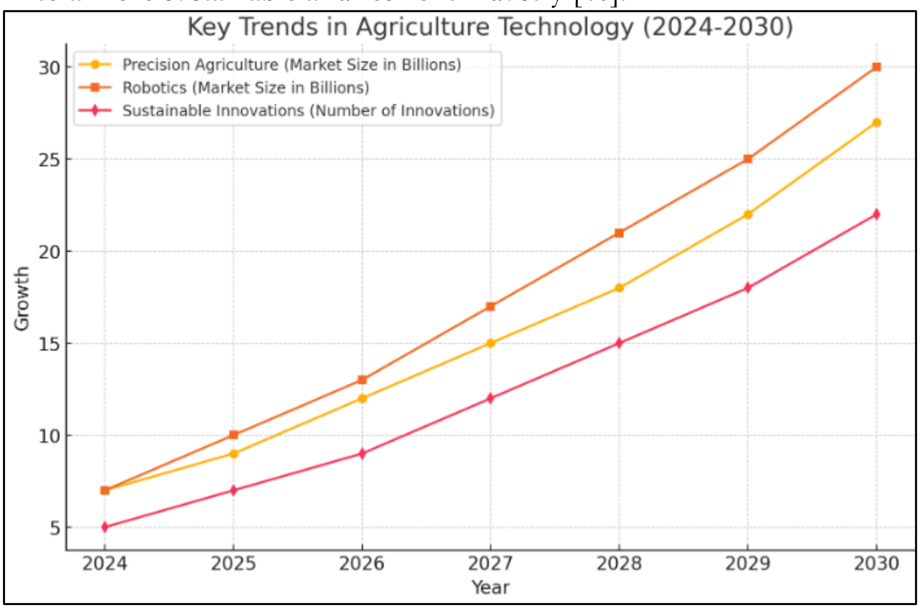

Figure 1: The projected growth of key trends in agriculture technology from 2024 to 2030

The graph above illustrates the projected growth of key trends in agriculture technology from 2024 to 2030:

Assembly:

Harvesting plays a vital role in the agricultural industry's crop production process as it has a direct impact on both the crop yield and overall crop performance. The United States is expected to experience labor shortages, leading to agricultural losses amounting to a yearly cost of USD 3.1 billion. As to the United States Department of Agriculture (USDA), labor and wages account for approximately 14% of the overall agricultural expenses, but can rise to as high as 39% on some labor-intensive farms. Agricultural experts predict that the integration of robotics technology in agriculture would not only alleviate the scarcity of human labor but also offer flexible harvesting capabilities as required, considering the present issues of cost and limited workforce availability. To accomplish automated fruit harvesting, it is crucial to do extensive research on advanced sensors that can gather accurate and unambiguous data related to specific crops and fruits.

Strawberries, for instance, are a frequently consumed fruit year-round. However, labor, especially during the packaging and harvesting phases, significantly contributes to the increased cost of this fruit. The implementation of the harvesting robot can significantly decrease production costs as a result of the prevalent growing of this fruit in greenhouses. An Agrobot robot can effectively pick strawberries and improve packaging in the field with the aid of an operator. It accomplishes this by traversing the rows of strawberry plants. Agrobot's SW 6010 is a partially automated robot specifically engineered for the task of harvesting strawberries. The Tektu T-100 is an electronic device designed for harvesting strawberries, and it operates using a rechargeable battery for electricity. It does not release any emissions when used in various environments.

Utilizing unmanned aerial vehicles (UAVs) to improve and bolster agricultural methodologies the Internet of Things is presently a noteworthy catalyst in diverse sectors, particularly in the agriculture industry, specifically in the domains of fish and poultry. The agriculture industry has a restricted communication infrastructure, leading to less availability of internet technologies. This network consists of both Wi-Fi and base stations. An obstacle of great importance to the adoption of the Internet of Things in agriculture is the inadequate quality of advanced communication technologies in less developed nations. In less developed nations, the data gathered by sensor devices is not effectively transported for processing due to a deficiency in dependable connectivity infrastructure. Unmanned aerial vehicles (UAVs) offer an alternate means of collecting data in such situations, which can then be processed and evaluated. In addition, unmanned aerial vehicles, equipped with state-of-the-art wireless sensors, multispectral, hyperspectral, and thermal cameras, have the capacity to effectively gather data from extensive agricultural areas. Currently, the use of Unmanned Aerial Vehicles (UAVs) in agriculture has the capacity to tackle numerous significant and long-lasting problems, leading to significant benefits. We showcase some prominent instances in which unmanned aerial vehicles (UAVs) have provided aid to farmers across the globe during every stage of the agricultural process.

Analysis of Soil and Water:

Before starting agricultural agriculture, advanced technology like unmanned aerial vehicles (UAVs) can provide precise data for assessing soil and soil moisture levels. This data can aid in determining the optimal crops to cultivate on a specific piece of land. Furthermore, it can offer detailed information regarding the type of seed and the exact techniques for cultivating it in various soil types and conditions. Horticulture refers to the practice of cultivating and growing plants, particularly for ornamental purposes or for food production.

Presently, there exists a worldwide deficit of skilled workforce or logistical obstacles that hinder the cultivation of millions of acres. The main obstacle to using these places for forestry or agricultural is the inherent safety risk presented by the difficult topography. Researchers are currently working on the development of drone-based seeding techniques that can result in significant cost savings of up to 85% in sowing expenses. The use of sophisticated drones not only reduces costs but also significantly improves planting efficiency, since they are capable of planting up to 100,000 trees in a single day. These systems produce reproductive structures known as shoot pods that contain seeds, which are vital nutrients necessary for the development and maturity of plants. The effectiveness of this strategy on difficult terrain exceeds 75%, indicating a high rate of success. Due to their adaptability and efficiency, the suggested drones have the capacity to become sophisticated agricultural systems on a global scale.

Irrigation refers to the process of supplying water to land or crops to help them grow and thrive. There are two advantages of using Unmanned Aerial Vehicles (UAVs) in irrigation applications. At first, outfitting drones with various cameras and sensors can assist in detecting regions facing water constraint and assessing the quantity of water required for cultivation. In addition, drones can be employed to precisely apply pesticides, herbicides, and irrigation to crops, especially in crucial circumstances, so maximizing time effectiveness. Moreover, Unmanned Aerial Vehicles (UAVs) possess the potential to evaluate and measure agricultural water stress. Technological advancements have enabled these unmanned aerial vehicles (UAVs) to function as water-saving devices. Unmanned aerial vehicles (UAVs) have the capability to enhance watering efficiency and detect irrigation leaks or potential water losses. Two unmanned aerial vehicles (UAVs), the JT20L-606 and AGRASMG-1, have been specifically designed for this specific purpose.

Present Obstacles and Potential Situations:

In 2015, the United Nations formulated initiatives to expedite the achievement of sustainable agricultural development by the year 2030. The most recent statistical data from the World Health Organization (WHO) appears to be discouraging for the prospects of sustainability. According to this method, around 800 million individuals, which is equal to one-ninth of the global population, suffer from worldwide food shortages. In order to tackle these problems, it is crucial to enhance grain production on a worldwide level. To fulfill the requirements of the industry, it is imperative to enhance the growth of lucrative crops like cotton and rubber. By the year 2030, there will be a substantial surge in the need for bioenergy, specifically ethanol.

This evaluation provides an overview of the primary obstacles that the agriculture industry will encounter by the year 2050. Primarily, this evaluation focuses on two key queries. (1) How can the latest technological breakthroughs help in providing food for a population of almost 10 billion people? and (2) improve agricultural yield without the need for more area for cultivation? Moreover, these problems present other difficulties, including a decrease in the amount of arable land, a scarcity of water resources, the consequences of climate change, and a decline in the agricultural labor force. Moreover, with the increasing urbanization, rural areas are not only witnessing a decline in population but also undergoing a rapid process of aging. Therefore, young farmers must assume greater responsibility. The demographic inequalities and transfers between generations would significantly affect the administration of agricultural activities and the availability of workforce in rural areas. Furthermore, even though there has been a decline in the amount of land suitable for farming, there are many places where only a limited variety of crops may be grown due to environmental and topographical limitations. Furthermore, nearly all agricultural crops are presently being impacted by the effects of climate change. These alterations are anticipated to exacerbate numerous preexisting chronic ecological problems, including increased flooding, turf erosion, soil deterioration, depletion of groundwater, and other related issues.

In contrast to wealthy nations, a majority of the population in developing countries are engaged in agricultural work, either through direct involvement or indirect means. Nevertheless, in terms of both quantity and quality, they lag far below prosperous nations. Less than 2% of the world's population lives in developed countries, where living conditions are much better. Australia, the United States, and the majority of European nations have implemented advanced tools and methodologies, hence emphasizing this differentiation. In the last fifty years, they have employed increasingly sophisticated technology and methodologies to improve agricultural output. These variants exemplify how sophisticated methodologies and cutting-edge technology improve the farm's productivity while maintaining its ecological sustainability.

The integration of technologies that leverage the capabilities of big data and artificial intelligence is anticipated to drive the advancement of the agriculture industry. The integrated systems will include a wide range of agricultural instruments, equipment, and methods that may be used for different agricultural management operations, such as forecasting crop yield and planting seeds. The application of cutting-edge technology such as big data, cloud computing, artificial intelligence, and agricultural robotics has the potential to usher in a new era of substantial integration in the agricultural industry. The subsequent are essential instruments and methodologies that will be indispensable for executing sustainable agriculture in the future.

The subject of discourse pertains to cellphones and the notion of the Internet of Things.

Cellphones and the Internet of Things have the capacity to transform agriculture in poor countries by enhancing market access and offering answers to various difficulties. Furthermore, these technologies possess the capability to narrow the divide between rural and urban areas, while also providing advantages to the future generation of producers. Due to the constraints of current distribution mechanisms, smartphone services pertaining to agriculture in impoverished nations have predominantly offered limited functionality. The Internet of Things (IoT) and quickly evolving smartphones have the capacity to bring about substantial change by providing several possibilities to create sophisticated services. Presently, people possess the capability to disseminate more complex information utilizing a wide range of gadgets. The usage and interconnection of smartphones and the Internet of Things (IoT) have concurrently risen as a result of the proliferation of smartphone networks. Technological progress has made it possible to gather and analyze large amounts of data to support agricultural practices and create online platforms for educational and informative sharing.

Although this article provides relevant information and outcomes, additional research is needed to determine the most effective utilization of the latest methodologies and technologies to enhance agricultural practices in underdeveloped countries. What are the precise obstacles that exist and what is required to overcome them? Developers of smartphone and Internet of Things technologies should not only focus on creating new equipment that may not be affordable for farmers with limited resources. They should also make sure that their services cater to a wide variety of consumer needs.

The term "Internet of Things and Wireless Sensors (IoTWS)" describes a network of interconnected devices and sensors that communicate wirelessly to gather and exchange data.
Strategically placing IoTWS (Internet of Things Weather Stations) in fields allows growers to obtain current information and data, enabling them to make required adjustments and ultimately improve agricultural production. The Internet of Things (IoT) can play a crucial role in agricultural operations to advance sustainable farming practices. This encompasses notifications related to the upkeep and operation of agricultural equipment, the efficient use of water and power, the transportation of goods, and the most recent market pricing. It possesses the capability to determine the precise requirements of crops at each stage, so streamlining and improving the effectiveness of these tasks. This technology has showcased its ingenuity and will grant farmers unparalleled authority over their property and assets, consequently transforming our understanding of diverse agricultural techniques to optimize their efficacy and productivity. Furthermore, the advancement of wireless sensor networks and fifth-generation (5G) smartphone communication technologies will have a substantial impact on the development of future Internet technology. This will provide growers with crucial updates at any location and time. Based on existing achievements, it is projected that the agriculture industry would employ more than 75 million internet-connected devices by 2021. In addition, it is estimated that by 2050, a typical farm will consistently generate 4.1 million data points.

Interaction or Dynamic Exchange Between Two or More Entities.

The efficacy of IoT in agriculture will predominantly rely on enhanced connectivity. Connectivity and other value-added vital services have diverse applications in telecommunications and can have a substantial impact on the whole network. Although telecommunications firms offer connectivity services, the advanced agriculture sector is predominantly dominated by private enterprises, which constitute only a small fraction of these public services. Given its importance, particularly in isolated areas, mobile network providers should provide farmers with a variety of cutting-edge services. Given that a substantial segment of the community possesses less formal education and thus faces difficulties in comprehending new technologies, operators should provide complete solutions that extend beyond mere connectivity. As a result, this will result in an increase in the market share of telecommunications providers and smartphones. Peters analyzed 23 evaluations, primarily conducted in developing nations, and concluded that the integration of smartphone technology and cellular networks has provided small-scale farmers with a favorable prospect, allowing for the potential improvement of agricultural yield. Having dependable connectivity is crucial in the agriculture sector.

Unmanned Aerial Vehicles (UAVs) and Other Automated Machinery:

Farmers and producers use unmanned aerial vehicles (UAVs) to assess crop growth, monitor environmental landscape features, biodiversity, and other variables. In addition, Unmanned Aerial Vehicles (UAVs) can be efficiently utilized for the purpose of water spraying and pesticide application in difficult farmland terrains, especially when farmers are required to cultivate crops in such regions. Robots and drones have demonstrated their exceptional capacity to spray with rapidity and accuracy, outperforming conventional technologies in the identical work. Advancements in task-based control and swarm technologies have enhanced the ability of groups of drones and robots, together with tools such as 3D cameras, to work together and provide producers with comprehensive land management capabilities. The implementation of robotics, in conjunction with the utilization of drones, has significantly improved agricultural productivity and effectiveness within the agricultural industry. Robots are reducing the need for pesticides by doing chores such as weeding and spraying.

Artificial Intelligence and Machine Learning:

Data is extracted for the aim of trend analysis using artificial intelligence (AI) and machine learning (ML). Machine learning and artificial intelligence are utilized in the field of agriculture to study and identify the genes that are most favorable for the cultivation of high-yielding crops. This provides improved seed types tailored to certain temperatures and places for farmers globally. Machine learning and artificial intelligence systems have shown the ability to distinguish between highly desirable items and those that are difficult to obtain. Growers can employ this information to their advantage for future agricultural methods. Advancements in machine learning and artificial intelligence (ML/AI) will allow growers to accurately classify their crop products and reduce the waste of valuable goods before planting.

The discussed topics encompass energy consumption, eco-friendly energy sources, microgrids, and sophisticated power distribution systems. Notwithstanding technical advancements, modern agriculture still encounters specific obstacles that impede the wider adoption of the Internet of Things. A significant concern regarding energy and power usage lies in the considerable energy requirements linked to sophisticated agricultural practices. The main elements that lead to high energy consumption are the long length of sensor deployment, the frequent transmission of sensing data using general packet radio service, and the use of GPS. Historically, farmers in rural areas have primarily limited their adoption of sophisticated agricultural techniques by haphazardly purchasing and utilizing renewable energy at exorbitant expenses. Conducting a thorough examination of the power source, such as remote information transfer, can help to address the long-term energy problem to some extent. Furthermore, farmers have readily adopted smart grids and microgrids because of its capacity to effortlessly incorporate distributed energy sources (DER). Smart meter installation has given farmers more confidence to engage in distributed energy resources (DER) by enabling them to send any excess electricity to the grid. Users residing in distant regions should be provided with alternate rechargeable devices or energy storage solutions, such as thermal, electrical, or mechanical systems, to offset the lack of a reliable energy source. The ongoing advancements in electricity, heating systems, and energy storage devices will augment the cognitive capabilities of distributed energy resources (DER) for agricultural purposes. When required, they will possess the capacity to store energy and harness the thermal energy produced by heating and cooling. Two further challenges that hinder the accomplishment of these projects are the need for a significant financial investment and extensive public awareness.

Implement Vertical Farming Methods and Utilize Hydroponic Systems.

Integrating state-of-the-art technologies is just as important as embracing innovative farming techniques to overcome limitations in resources and geography. The quantity of cultivable land is decreasing, while an estimated 3 million individuals have migrated to metropolitan areas globally, hence exacerbating the pressure on the already limited resources available to cities. According to the present growth rate, it is estimated that by 2030, 60% of the world's population would live in urban regions, and by 2050, this percentage is predicted to rise to 68%. Considering the current agricultural practices, it is possible for food production to be extremely harmful due to these two challenges. VF is an optimal approach for addressing difficulties linked to land management and water scarcity, particularly in urban areas. The problem of food shortages and the exhaustion of arable land is portrayed as obstacles that could potentially be resolved by the adoption of Vertical Farming (VF), particularly in specific regions of the globe. Furthermore, hydroponics provides substantial benefits by effectively minimizing the requirements for both space and water. Farmers are increasingly drawn to water and nutrient-efficient farming methods, such as vertical farming, due to the rapid advancements in technology. Moreover, the utilization of sophisticated methods such as hydroponics and vertical farming is necessary to increase arable land while simultaneously protecting the integrity of natural animal habitats and forests. In order to do this, it is imperative to focus on the desert, which comprises 33% of the Earth's overall land area. Norwegian and Chinese enterprises and professionals are partnering to provide solutions in the desert regions of Dubai, Qatar, Jordan, and China. The Internet of Things (IoT) and other cutting-edge technologies are essential for accomplishing this goal.

The demand for food escalates as the global population continues to expand. As a result, arable land and forests are being replaced by urban areas. The growing world population requires higher food production, which in turn requires the employment of highly efficient and modern technology due to limited arable land. Currently, one can easily observe the advancements in cutting-edge methods that aim to improve crop productivity and enhance other agricultural processes. Some individuals lacking technological aptitude choose to pursue a profession in agriculture. Despite the various alliances and joint efforts between suppliers, farmers, retailers, and customers, there is still a significant lack of effective communication. There is a pressing need for cutting-edge and sophisticated technology to close this gap. This review explores several agricultural technology topics and highlights the pivotal role those modern technologies, namely the Internet of Things, play in advancing agriculture to achieve future objectives. Furthermore, sustainable agriculture requires the use of cutting-edge technology, including cloud computing, remote and ground sensors, communication technologies, and unmanned aerial vehicles. This review offers a deeper comprehension of the most recent research discoveries. The aforementioned pertinent data clearly illustrates the pressing need for agricultural production and advancement. Nevertheless, it is imperative to incorporate these cutting-edge and groundbreaking technologies, such as the Internet of Things. By embracing these cutting-edge technologies, farmers will enhance their agricultural practices and resources. The progress of cutting-edge technologies will facilitate the adoption of sustainable agriculture.

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