RECENT TRENDS IN AGRICULTURAL ENGINEERING AND FOOD SCIENCES: A FUTURISTIC APPROACH

Abstract

This study undertakes a comprehensive analysis of the historical, contemporary, and prospective trends in agricultural engineering and food science, observing the transformation from conventional methods to innovative and sustainable practices. Starting from classical times, we trace how agricultural engineering, once characterized by rudimentary tools and practices, experienced significant shifts during the Agricultural Revolution in the 18th and 19th centuries, which introduced mechanization and selective breeding. We identify the impact of these advancements, while also acknowledging the sustainable issues they precipitated, including land degradation and reduced genetic diversity. Focuses on examinations of 20th century's 'Green Revolution', which introduced chemical fertilizers, hybrid crops, and advanced irrigation systems, improving productivity but exacerbating environmental concerns. At this juncture, the study converges with the evolution of food science, which has experienced parallel advancements. It began with rudimentary food preservation techniques and evolved through Louis Pasteur's pasteurization process in the 19th century, culminating in the industrialization of food production in the 20th century. Eventually the chapter emphasizes 21st-century focus on sustainable and resilient agricultural systems and nutritious, safe food supply chains. We explore novel trends in agricultural engineering such as precision farming, genetic modification, vertical farming, and use of AI and IOT for predictive analytics and automation. In the realm of food science, proposed research delve into innovations like

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nutri-genomics, alternative proteins, and advanced food processing and packaging technologies. The study asserts that this futuristic approach, underpinned by ethical considerations and sustainability, promises a transformative impact on global food security and environmental health. By encapsulating the vast journey from the rudimentary practices of the past to today's high-tech, sustainability-focused strategies, this study provides critical insights into the evolution and future trajectory of agricultural engineering and food science

Highlights of Chapter

- Using digital technologies, agriculture 4.0 is the fourth agricultural revolution.
- New agricultural technology has been developed to improve sustainability and find more efficient farming practises.
- The necessity of smart farming incorporating AI and IOT in Agriculture 4.0 is briefly discussed in this study.
- A detailed discussion of many Key Technologies and particular topics for investigating the Agriculture 4.0 domain is provided.
- Identification & discussion about key Agriculture 4.0 technology applications.

Keywords: Agricultural engineering, Food science, Sustainable practices, Green Revolution, Nutri-genomics

I. INTRODUCTION

Agricultural engineering and food sciences are going through a transformative phase owing to the integration of advanced technologies. These disciplines are witnessing revolutionary trends and progress that are reshaping traditional methods and introducing more efficient, accurate, and sustainable practices. Agricultural Engineering and Food Sciences, two disciplines crucial to the sustenance and growth of human society, are standing on the brink of a revolution driven by technological advancements and innovative practices. While the primary objective of these sectors remains rooted in enhancing productivity and sustainability, the modalities of achieving these goals are rapidly changing in response to the advent of cutting-edge technologies. This introduction provides a comprehensive overview of the ongoing transformation in these sectors, emphasizing emerging trends and technologies.

The role of Agricultural Engineering is undoubtedly multidimensional; multifaceted that encompasses a wide spectrum of activities, from resource-efficient farming practices to post-harvest storage, and from mechanization to renewable energy utilization. At its core, the objective of this discipline is to leverage technology for optimizing efficiency, reducing environmental impact, and enhancing the profitability of agricultural activities. Similarly, Food Science focuses on understanding the nature of foods and the principles underlying their preservation, processing, and packaging, thereby ensuring food safety, quality, and nutrition.

Technological advancements have spurred a wave of innovations across these fields, redefining traditional practices and setting new standards of productivity, sustainability, and efficiency. A prominent example of this is Precision Agriculture, a technique that uses technology to fine-tune farming practices to the specific needs of individual crops and soils. This approach relies on technologies such as remote sensing, Global Positioning Systems (GPS), and Geographic Information Systems (GIS) to collect, analyse, and interpret data regarding field conditions, thereby enabling farmers to optimize their input application strategies **[1]**.

Similarly, the Internet of Things (IoT) is contributing to more intelligent and efficient farming practices by facilitating real-time monitoring of various agricultural parameters. IoT devices, including smart sensors and automated systems, allow for efficient data collection and analysis, providing farmers with actionable insights that help improve crop health, yield, and resource use efficiency **[2]**. These technologies bond together laying the foundation of smart farming or digital agriculture, an emerging trend that integrates digital technology into farming systems, enhancing their performance and sustainability.

Parallelly, the realm of Food Science is also undergoing significant transformations catalyzed by technological progress. From the use of nanotechnology in improving food packaging and shelf-life, to employing biotechnology for enhancing food nutritional content, and even leveraging artificial intelligence (AI) for developing new food products, the scope and breadth of Food Science have expanded considerably over recent years **[3]**.

In addition to these, various other technologies such as Variable Rate Technology (VRT), Agricultural Robotics, Big Data & Analytics, and Emission Reduction Technology are increasingly finding application in agricultural engineering and food sciences. VRT allows for the precise application of inputs based on the specific needs of different areas within a field, thus enhancing productivity while minimizing environmental impact **[4]**.

Agricultural Robotics, on the other hand, is mechanizing labour-intensive tasks such as planting, weeding, and harvesting, thus saving time and effort while enhancing operational efficiency **[1]**. Big Data & Analytics are being employed to analyze vast amounts of data collected from various sources, enabling prediction of trends, improving decision-making, and aiding in resource management and disease prediction **[5]**.

Emission Reduction Technology, simultaneously is becoming increasingly important in the face of climate change, that involves practices like precision farming, carbon sequestration, and anaerobic digestion that help reduce the environmental footprint of agricultural activities **[6].**

The transformation of Agricultural Engineering and Food Sciences brought about by these technological advancements holds immense potential for addressing some of the most pressing challenges of current time, such as food security, environmental sustainability, and climate change. As these sectors continue to evolve, it becomes imperative to study and understand these changes, for they hold the key to our future.

The integration of Artificial Intelligence (AI) and the Internet of Things (IoT) in agriculture, often referred to as “AgTech” or “Smart Farming”, has been a transformative force in recent years. This convergence has the potential to revolutionize various aspects of agriculture, from crop management to livestock monitoring**.[7]**

The demand from a population that is expected to increase to 9.6 billion people by 2050 would require the agriculture sector to develop. In order to fulfil such ever-surging demands of the expanding population, the agriculture sector will need to embrace novel technology and acquire a crucial advantage likewise. The agricultural sector will be able to enhance yield quality, save costs, minimize waste, and boost operational efficiency with new IoT applications. **[8]**

A high-tech, capital-intensive method of producing sustainable, clean food for the general public is called "smart farming." In agriculture, it refers to the use of contemporary ICTs (information and communication technologies).

Using sensors for light, humidity, temperature, and soil moisture, a system in IoT-based smart farming keeps an eye on the agricultural field and triggers the irrigation system automatically. Farmers are able to keep an eye on field conditions from any location. Smart farming based on the Internet of Things is evolving to be far more efficient than traditional Farming methods. **[9, 10]**

In addition to improving traditional, large-scale operations, IoT-based smart farming apps also promote organic, family, and transparent farming trends. Optimizing inputs and treatments or using water more efficiently are two further benefits of smart farming. Considering the main uses of IoT-based smart farming that are transforming the agricultural industry. **[11]**

This chapter aims to provide a comprehensive review of the recent trends in Agricultural Engineering and Food Sciences, delving into the various emerging technologies andtheirimplications.Byexaminingthecurrentstateoftheselectorsandexploringpotential future trajectories; we aim to contribute to the discourse surrounding these transformative developments and their role in shaping the future of food production and consumption.

1. Emerging Trends in Agricultural Engineering and Food Sciences

- **Satellite Technology:** Remote sensing and GIS have revolutionized agricultural practices by providing detailed and accurate information regarding soil health, crop health, and weather patterns. These data-driven insights assist farmers in making informed decisions regarding crop selection, fertilization, irrigation, and harvest timings. Satellites, such as those in NASA's fleet, are critical for monitoring crop health, soil moisture, and predicting weather patterns **[7]**.

- **Internet of Things (IOT):** IOT devices and sensors are becoming increasingly popular in precision agriculture. These devices collect real-time data on various agricultural parameters like soil moisture, crop health, weather conditions, and more. This data can then be analyzed and used to improve agricultural efficiency and productivity **[2]**.

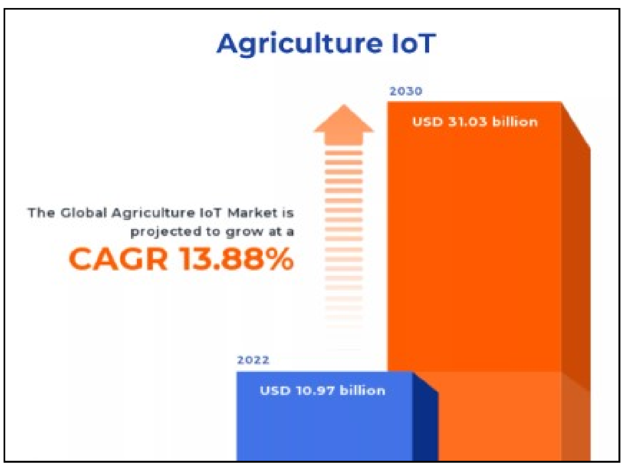

Figure 1: Estimated Statistics for global agricultural IOT market **[12]**

- **Artificial Intelligence (AI):** AI is making a significant impact on both agricultural engineering and food sciences. Machine learning models are being used to predict crop yields, identify pests, and optimize irrigation. In food sciences, Is being used in developing new food products, ensuring food safety, and personalizing nutrition **[13]**.

- **Variable Rate Technology (VRT):** VRT allows for more precise application of inputs such as seeds, fertilizers, and pesticides based on the specific needs of different sections within a field. This technology helps in reducing waste, increasing yield, and maintaining soil health **[4]**.

- **Agricultural Robotics:** Robotic technology is being utilized in tasks such as planting, pruning, weeding, and harvesting. This reduces the dependency on manual labour and improves the speed and efficiency of agricultural operations **[1]**.

- **Big Data & Analytics:** The use of big data in agriculture enables the analysis of vast amounts of data collected from various sources to provide actionable insights, predict trends, and improve decision-making processes. It aids in resource management, crop yield prediction, and disease prediction **[5]**.

- **Emission Reduction Technology:** With climate change becoming an imminent threat, technologies that reduce agricultural emissions are being highly sought after. This includes practices like precision farming, carbon sequestration, anaerobic digestion, and more **[6]**.

2. **Future Prospects / Scope of AI in Agricultural Engineering and Food Sciences:** Artificial Intelligence (AI) is poised to be the most significant technology driving the future of agricultural engineering and food sciences. For the coming decades, it's anticipated that AI will reshape every aspect of the food production chain. In agriculture, we can expect AI-driven agribots to perform tasks with more precision and efficiency, coupled with machine learning algorithms to predict crop diseases and pests in advance.

   Food sciences will also witness a paradigm shift as AI will allow for the creation of personalized nutrition plans based on an individual's genetic makeup, lifestyle, and preferences. Moreover, AI will further optimize food processing and packaging, reducing waste, and enhancing food safety protocols **[14]**.

   To conclude, the future of agricultural engineering and food sciences lies in harnessing these evolving technologies, which promise to tackle current and future challenges, ensuring food security and sustainability.

3. **Advantages of AI and IoT in Futuristic Agriculture**

- **Increased Efficiency:** AI and IoT enable real-time monitoring and data analysis, leading to more efficient use of resources.
- **Optimized Resource Management:** Precision agriculture techniques ensure optimal use of water, fertilizers, and pesticides.
- **Early Detection and Response:** Rapid detection of diseases and pests allows for timely interventions, preventing widespread crop damage.
- **Data-Driven Decision Making:** Farmers can make informed decisions based on data analytics, weather predictions, and historical trends.
- **Sustainability:** Reduced environmental impact through precise resource management and sustainable farming practices. **[15-17]**

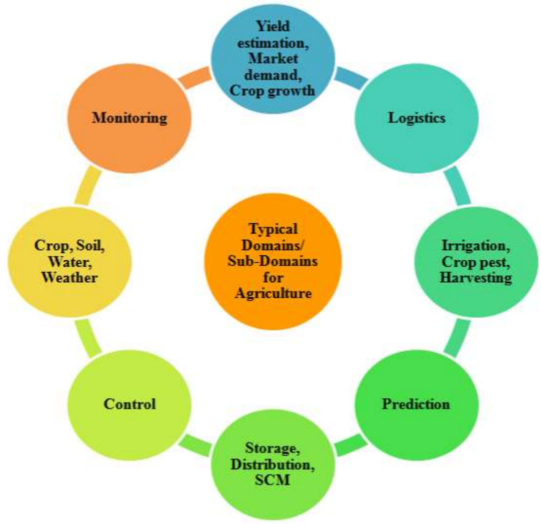

Figure 2: AI and IoT implications for diverse domains in Agriculture sectors

4. **Below are some smart practices and sources that can provide figures, info graphics, and relevant information on the recent trends, futuristic approaches, and advanced applications of AI and IoT in agriculture: [18-20]**

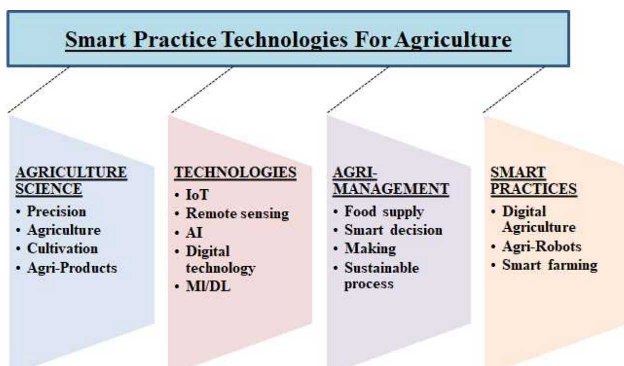

Figure 3: Advance applications of AI and IoT in Agriculture

- **Artificial Intelligence (AI):** AI refers to the simulation of human intelligence in machines programmed to think and learn like humans. It encompasses a wide range of technologies, including machine learning, natural language processing, computer vision, and robotics. In the context of agriculture, AI can analyze large sets of data to make predictions, automate tasks, and optimize processes.

- **Difference between AI and IoT:** AI focuses on creating intelligent systems that can mimic human cognitive functions, such as learning, problem-solving, and decision-making. IoT is about connecting physical devices and enabling them to collect and exchange data, creating a network of interconnected objects.

- **Internet of Things (IoT):** IoT is a network of interconnected devices that communicate and share data with each other over the internet. In agriculture, IoT involves the use of sensors, actuators, and other devices to collect and exchange data. This data can be related to soil moisture, weather conditions, crop health, and more. The goal is to enhance decision-making processes and enable more efficient and precise agricultural practices.

5. Dimensions of AI Applicability in Agriculture

- **Precision Farming:** AI can analyze data from various sources like sensors, drones, and satellites to optimize planting patterns, irrigation, and harvesting, leading to increased efficiency and higher yields.
- **Crop Monitoring:** AI-powered image recognition can assess crop health, detect diseases, and pests, allowing for early intervention and reducing crop losses.
- **Supply Chain Optimization:** AI helps optimize logistics, storage, and distribution, ensuring that crops reach markets efficiently and reducing waste.
- **Predictive Analytics:** AI algorithms can predict weather patterns, market trends, and crop diseases, enabling farmers to make informed decisions.
- **Autonomous Machinery:** AI-driven autonomous tractors and harvesters can perform tasks without human intervention, increasing productivity and reducing labor costs.

6. AI's Impact on the Future of Agriculture Engineering

- **Increased Efficiency:** AI enables the automation of routine tasks, freeing up time for farmers to focus on more strategic and complex aspects of agriculture.
- **Sustainability:** Precision farming and resource optimization contribute to sustainable agriculture practices, reducing environmental impact.
- **Global Food Security:** AI can help address challenges related to population growth by maximizing crop yields and improving the overall efficiency of food production

II. GLOBAL IMPLICATIONS AND INITIATIVES

1. **United States:** The U.S. Department of Agriculture (USDA) has invested in AI and IoT technologies for precision agriculture. Companies like John Deere and IBM have played significant roles in advancing smart farming.

2. **Europe:** The European Union has been promoting digital agriculture through initiatives like the European Innovation Partnership for Agricultural Productivity and Sustainability (EIP-AGRI).

3. **Germany:** German agricultural machinery manufacturers, including Bayer and Claas, have integrated AI and IoT into their products to enhance precision farming.

4. **Israel:** Israel, with its focus on agtech, has seen startups like Taranis using AI for crop monitoring and disease detection.

5. **Brazil:** Brazil has adopted precision agriculture with AI and IoT applications for optimizing sugarcane and soybean production.

III. INITIATIVES IN INDIA

1. **IIT Initiatives:** Indian Institutes of Technology (IITs) are conducting research on AI applications in agriculture. For instance, IIT Kharagpur has been involved in developing AI-driven crop monitoring systems.

2. **IIMR (Indian Institute of Millets Research):** IIMR is exploring the use of IoT for millet cultivation, aiming to enhance yields and promote millet-based farming systems.

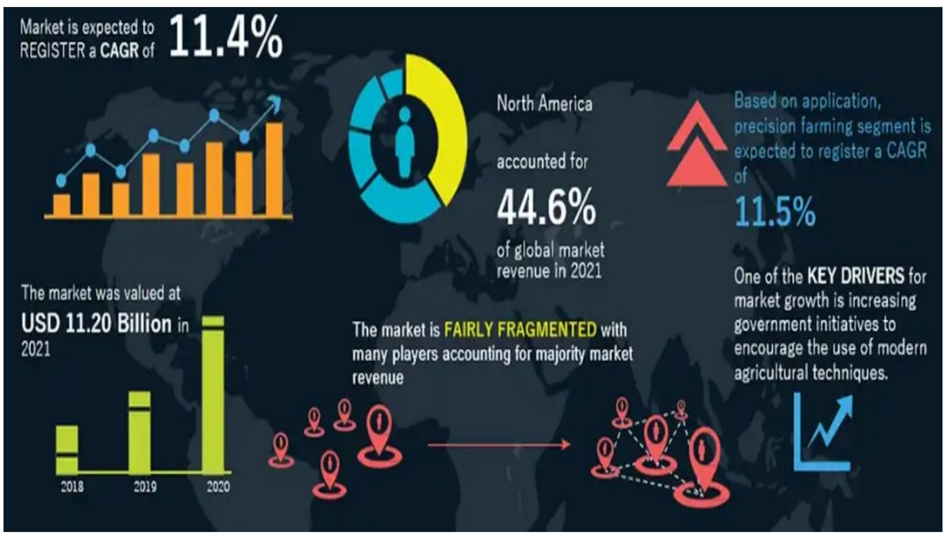

Figure 3: Market Info graphics for modern agricultural techniques and its rising CAGR **[21]**

IV. CASE STUDIES FOR AI & IOT FOR AGRICULTURAL ENGINEERING AND TRENDS IN FUTURE

1. Precision Agriculture

- **Case Study:** John Deere's use of IoT and AI in precision agriculture. John Deere employs AI algorithms to analyze data from sensors on tractors and other farming equipment. This helps farmers optimize planting, irrigation, and harvesting.
  - **Advantages:** Increased efficiency in resource utilization, improved crop yields, and reduced environmental impact. **[22]**

2. Crop Monitoring and Disease Detection

- **Case Study:** IBM Watson Decision Platform for Agriculture. IBM's AI platform uses machine learning algorithms to analyze data from various sources, including drones and sensors, to monitor crops, detect diseases, and recommend appropriate actions.
  - **Advantages:** Early detection of diseases, reduced crop losses, and optimized use of pesticides. **[23]**

3. Smart Irrigation

- **Case Study:** Netafim's use of AI in drip irrigation. Netafim employs AI algorithms to analyze weather data, soil moisture levels, and crop conditions to optimize irrigation schedules.
  - **Advantages:** Water conservation, increased crop yield, and cost savings. **[24]**

4. Autonomous Farming

- **Case Study:** Hands Free Hectare project in the UK. This project utilized AI and autonomous machinery to plant, tend, and harvest a crop without human intervention.
  - **Advantages:** Increased efficiency, reduced labor costs, and 24/7 farming operations. **[25]**

V. NOVEL APPLICATIONS OF IOT IN AGRICULTURAL ENGINEERING AND FOOD SCIENCES

1. **Precised Agriculture:** Precision farming, also known as precision agriculture, refers to any technique that improves the accuracy and control of rearing cattle and cultivating crops. Utilizing IT, sensors, robotics, control systems, autonomous cars, automated hardware, and so forth is essential. Manufacturers' interest in precision agriculture is fueled by several technologies, including inexpensive satellites, mobile devices, and high-speed internet. One of the most widely used IoT applications in the agriculture industry is precision agriculture.

   Crop-Metrics is a precision agriculture company that specializes in precision irrigation management and emphasizes cutting-edge agronomic solutions. Crop-Metrics offers a variety of goods and services, such as virtual optimizer PRO, soil moisture sensors, and VRI optimization. On irrigated crop fields, VRI (Variable Rate Irrigation) optimization, maximizing impactful water efficiency. The soil moisture probe technology offers suggestions to maximize water usage efficiency as well as full in-season local agronomy support. Through a user-friendly interface, the virtual optimizer PRO consolidates many water management technologies into a single, robust, cloud-based site that allows consultants and growers to benefit from precision irrigation.

2. **Drones:** Drones for Agriculture currently, one of the main sectors using IoT drones is agricultural. Drones, both airborne and ground-based, are being used by farmers for planting, irrigation, crop health assessment, crop monitoring, crop spraying, and soil and field study.

   Drone usage has several advantages, including the ability to improve yields, convenience of use, time savings, integrated GIS mapping, and crop health imaging. Drone technology will offer the agriculture sector a high-tech makeover with strategy and planning based on real-time data collecting and processing. Precision-Hawk is a company that uses drones that are fitted with a variety of sensors to map, image, and survey terrain in order to collect important data. These drones conduct observations and monitoring while in flight. The farmers input the specific fields to be surveyed and select an altitude or ground resolution. Drone data can be used to measure plant health indices, count plants and estimate yields, measure plant height, map canopy cover, map field water ponding, provide scouting reports, measure stockpiles, measure chlorophyll, measure wheat's nitrogen content, map drainage, map weed pressure and more. During the flight, the drone gathers multispectral, thermal, and visual imagery. It then lands in the exact spot from where it took off.

3. **Livestock Monitoring:** Big farmers may gather information on the whereabouts, health, and welfare of their cattle by using wireless Internet of things apps. By identifying and removing diseased animals from the herd, they can stop the spread of illness by using this knowledge. Because ranchers can use Io T-based sensors to detect their animals, it also reduces labor expenses.

   Cattle ranchers can use cow monitoring systems from JMB North America. A possible option is to assist cattle owners with monitoring pregnant and soon-to-give birth cows. A battery-operated sensor that alerts the rancher or herd manager when a heifer's water breaks is expelled. Farmers may concentrate their efforts and pay close attention to heifers giving birth thanks to this sensor.

4. **Astute Greenhouses:** A technique that aids in increasing the productivity of fruits, vegetables, crops, etc. is greenhouse farming. Greenhouses employ a proportional control system or manual intervention to regulate the environmental parameters. Manual intervention is less efficient since it costs money in employment, energy, and manufacturing. With their assistance, a smart greenhouse may be created effectively enabling utilization of IoT. This design does not require user intervention since it intelligently monitors and adjusts the climate. In order to regulate the environment in a smart greenhouse, several sensors detect environmental data specific to plant needs. The set up a cloud server to access the system remotely when connected via IoT can be explored enormously. This removes the requirement for ongoing human observation. The cloud server also performs a control action and permits data processing within the greenhouse. With the least amount of physical employment, this design offers farmers excellent and economical alternatives.

VI. IMPACT OF IOT IN AGRICULTURAL ENGINEERING AND FOOD SCIENCES

Thus, farmers and ranchers are now able to gather useful data thanks to IoT agricultural applications. If ranchers and small farmers use agricultural IoT technology, they can successfully meet the demands of our expanding population.

VII. CONCLUSION / SUMMARY

In the agricultural sector, agriculture 4.0 is an irreversible trend that cannot be stopped via personal mobile phones, these technologies may link people's modern connection. Because of their affordability and simplicity of use, smartphones, the Internet of Things, and artificial intelligence have made it possible for communication and information technologies to become increasingly integrated into the psycho-social structures of people, cities, and businesses. This integration has the potential to be discovered and utilized to great effect.

Today's agriculture is severely strained, mostly because of climate change, resource shortages, and worldwide population growth. In this case, agriculture 4.0 can be helpful since it decreases expenses for fuel, water, and energy while increasing crop yield and improving crop management decision-making. It also lessens the environmental effect of agricultural practices by lowering the usage of chemicals. By storing carbon in the soil, reducing greenhouse gas emissions, and raising agricultural systems' productivity and profitability, climate-smart agriculture seeks to both adapt to and lessen the consequences of climate change while preserving farmers' livelihoods and food security. A network of linked new farming gadgets will be formed by the convergence of IoT and precision agriculture techniques.

Commissioning IoT, precision farming may use a variety of strategies to address challenges in agriculture. Farmers are able to create strategies that are specific to their land and the current year by gathering data about their farms more rapidly. Irrigation, livestock, vehicle tracking, and many other precision agricultural techniques are critical to increasing productivity and effectiveness. Technologies in agriculture 4.0 enable the evaluation of soil conditions and other associated data to boost operational efficiency. These technologies may also determine the water and nutrient levels by detecting the real-time functioning characteristics of the connected devices.

Employing Agriculture 4.0 technology, farmers may utilize trend analysis to forecast future weather patterns and agricultural yields in the near future. Using IoT in agriculture will help farmers manage soil fertility and crop quality, which will increase production volume and quality. Better decision-making is made possible by the data that is gathered and utilized to capitalize on technology innovations. IoT devices will give real-time information regarding crop status by logging data from sensors. Making improved harvesting decisions may be possible with the use of predictive analytics. Improved production methods, automated agricultural equipment, and scientific planting techniques all contribute to the growth of the agricultural sector. Smart technology has the potential to usher in Agriculture 4.0 age.

Utilization of data from sensors and images to monitor crops, soil, and air in real time, precision farming enables farmers to detect and react to changes in specific areas in real time. Crop management devices are an IoT product used in agriculture and a component of precision farming. Predictive data analytics is inherently linked to precision agriculture. Data analytics helps farmers make sense of the vast amount of pertinent real-time data that IoT and smart sensor technologies offer. Critical forecasts, including crop harvesting time, disease and insect risks, yield volume, etc., may be made with the use of data analytics. The management and predictability of farming, which is mostly weather-dependent, are improved by data analytics techniques. Similar to weather stations, they will be placed in the field to gather information on temperature, precipitation, leaf water potential, and general crop health that is relevant to agricultural production.

Weather stations can automatically modify the circumstances to fit the predetermined criteria in the future, in addition to gathering environmental data. Crop management devices are an IoT product used in agriculture and a component of precision farming. Similar to weather stations, they will be placed in the field to gather information on temperature, precipitation, leaf water potential, and general crop health that is relevant to agricultural production. Thus this chapter encompasses and explores focal view point for foreseeing the implications of AI and IoT as ultra-modern tools for improvisation in recent Trends in agricultural engineering and Food sciences sectors.

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