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17. The Role of Digital Technology in Agriculture

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Abstract:

Digital agriculture is transforming farming and reducing hunger and poverty in rural areas, which is especially helpful for developing nations. Innovations such as blockchain, artificial intelligence (AI), precision agriculture, automation, livestock technology, indoor vertical farming, and precision agriculture are driving this shift. Mobile devices further boost efficiency and accessibility. The incorporation of digital technology has enhanced connectivity in fields including agronomy, communication, and machinery. Internet of Things (IoT), mobile solutions, and artificial intelligence (AI) are major forces behind these developments. Digital agriculture has many advantages, including enhanced tracking, decision-making, and communication; time and cost savings; enhanced operational efficiency through focused applications; and better productivity and profitability. Better marketing tactics, instantaneous information access, simplified record-keeping, improved risk management, and lessened regulatory requirements are further benefits for the industry. By using these digital technologies, agriculture can surpass traditional ways and become more efficient and sustainable, opening the door to a more affluent and productive future.

Keywords:

Digital agriculture, Sensors, Robotics, drones and block chain.

17.1 Introduction:

Three major revolutions in agriculture throughout history have changed the tools and methods used in the production of food. After the first revolution, people moved from a hunter-gatherer way of life to settled agriculture, where they started growing crops and rearing animals. With the introduction of tractors and combines during the second revolution, mechanization was implemented. By decreasing manual labor and increasing production, these devices changed farming techniques by improving efficiency in operations like planting, harvesting, and tilling. The usage of agrochemicals, such as fertilizers and pesticides, as well as developments in genetic engineering were brought about by the third revolution. These methods sought to maximize plant features, increase crop yields, and strengthen insect resistance. The rise of digital farming is the next big transformation that the agriculture sector is about to experience. In order to increase production, sustainability, and efficiency throughout the whole agricultural value chain, this transformation calls for the integration of cutting-edge technologies. Drones are essential to digital agriculture, as are other technologies like robotics, artificial intelligence, and sensors. Drones facilitate improved data gathering, archiving, and analysis, offering insightful information for agricultural decision-making processes. They can collect information on the health of crops, the behaviour of animals, and the state of the environment, enabling farmers to forecast the future and respond accordingly.

To sum up, digital agriculture is the fourth industrial revolution in the agricultural sector, and technologies such as robotics, AI, and drones are influencing farming in the future by enhancing data-driven choices, streamlining activities, and promoting connections across the supply chain.

17.2 Digital Agriculture:

17.2.1 Importance of Digital Technology in Agriculture:

Many facets of agriculture, such as fertilizers, pesticides, seed technology, automation, irrigation, and transportation networks, have been significantly impacted by technological breakthroughs.

These advancements have been essential in raising agricultural yields, enhancing the quality of food and fiber, lowering the need for human labor, and achieving food self-sufficiency. When compared to traditional agricultural practices, digital agriculture offers many advantages that increase farming's efficiency and sustainability.

Through the use of digital tools, mobile solutions, machine learning, and the Internet of Things (IoT), the agricultural sector can experience significant advantages. Digital agriculture offers a multitude of benefits, viz.,

Improved Communication and Connectivity:

a. Enhanced Collaboration: Digital platforms and mobile applications enable farmers to connect with experts, suppliers, and markets more effectively. This fosters knowledge sharing and access to best practices.
b. Real-Time Updates: Farmers can receive timely information about weather conditions, pest outbreaks, and market prices, allowing for more informed decision-making.

Better Monitoring and Decision-Making:

a. Precision Agriculture: Technologies such as drones, satellite imagery, and soil sensors provide detailed data on crop health, soil conditions, and resource use. This allows for precise application of water, fertilizers, and pesticides, optimizing inputs and reducing waste.

b. Predictive Analytics: AI-driven models can predict crop yields, identify potential issues, and recommend optimal planting and harvesting times, leading to better planning and resource management.

Time and Cost Savings:

a. Automation: Automated machinery and robotic systems can perform tasks such as planting, weeding, and harvesting more quickly and accurately than manual labor, reducing labor costs and increasing efficiency.
b. Efficient Resource Use: Digital tools help optimize the use of resources like water and fertilizers, lowering costs and minimizing environmental impact.

Increased Operational Efficiency:

a. Targeted Applications: Precision tools enable farmers to apply inputs only where needed, improving efficiency and reducing waste. For instance, variable rate technology allows for the precise application of fertilizers based on soil nutrient levels.
b. Streamlined Processes: Digital record-keeping and farm management software simplify administrative tasks, reducing the time and effort required for documentation and compliance.

Higher Productivity and Profitability:

a. Yield Improvement: Enhanced monitoring and precise input application lead to healthier crops and higher yields. Advanced breeding techniques and genetically modified crops can also contribute to better performance.
b. Market Access: Digital platforms can connect farmers directly to buyers, reducing intermediaries and improving profit margins.

Better Marketing Strategies:

a. Data-Driven Marketing: Farmers can use data analytics to understand market trends, consumer preferences, and price fluctuations, enabling them to tailor their marketing strategies accordingly.
b. E-Commerce Platforms: Online marketplaces allow farmers to reach a broader customer base, increasing sales opportunities and reducing dependency on local markets.

Real-Time Information Access:

a. Weather and Climate Data: Access to accurate weather forecasts and climate information helps farmers plan their activities and mitigate risks associated with adverse weather conditions.
b. Market Prices: Real-time price updates enable farmers to make informed decisions about when and where to sell their produce.

Streamlined Record-Keeping:

a. Digital Records: Electronic record-keeping simplifies tracking of inputs, outputs, and financial transactions, ensuring accurate and easily accessible records.
b. Compliance and Reporting: Automated systems help ensure compliance with regulatory requirements and facilitate easy reporting for certifications and subsidies.

Better Risk Management:

a. Insurance and Financing: Digital tools can facilitate access to crop insurance and financing options, helping farmers manage financial risks and invest in their operations.
b. Early Warning Systems: Advanced monitoring systems can provide early warnings of pests, diseases, and other potential threats, allowing for timely intervention.

Reduced Regulatory Burdens:

a. Compliance Automation: Digital tools can automate compliance with regulations, reducing the administrative burden on farmers and ensuring adherence to legal requirements.
b. Traceability: Blockchain technology can enhance traceability in the supply chain, providing transparency and reducing the risk of fraud or non-compliance.

By embracing these digital tools, agriculture becomes more sustainable, efficient, and resilient, surpassing traditional methods and paving the way for a more productive and prosperous future.

17.2.2 Components of Digital Agriculture (Dayıoğlu and Turker 2021):

Agriculture is undergoing a major transformation, and digital technology is propelling innovation in many facets of the sector. An outline of important digital technologies in agriculture is provided below:

a) **Internet of Things:** IoT refers to the network connectivity of sensors and gadgets that gather and send data. IoT makes it possible to monitor temperature, moisture content in the soil, and other environmental parameters in agriculture. Farmers can use this information to make well-informed decisions about crop health, pest control, and irrigation.
b) **Agricultural sensors:** Farmers may maximize crop management by using the data from these wireless sensors, which are based on environmental conditions. They help with airflow evaluation, moisture detection, nutrient monitoring, soil analysis, and accurate location tracking. Farmers that use sensors can save labor and pesticide costs while applying fertilizer more effectively, increasing yields, and protecting the environment.
c) **Robotics and automation:** Robotic systems are increasingly usedin agriculture for tasks like planting, harvesting, and weeding. These technologies improve precision and efficiency while reducinglabor costs and physical strain on farmers.

- **d) Remote sensing and satellite imaging:** Remote sensing and satellite imaging techniques provide real-time and accurate information on crop conditions, vegetation health, and soil moisture levels. This data helps farmers monitor crop growth, detect diseases, and optimize irrigation practices.
- **e) Precision agriculture:** Precision agriculture utilizes GPS, GIS, and data analytics to optimize farm operations. Farmers can create detailed field maps, apply fertilizers and pesticides precisely, and monitor crop variability to maximize productivity and minimize resource waste.
- **f) Farm management software:** Farm management software enables farmers to streamline operations, manage inventory, track machinery maintenance, and monitor financial aspects of their business. These tools enhance efficiency and enable data-driven decision-making.
- **g) Blockchain technology:** Blockchain offers secure and transparent data management and transaction systems. In agriculture, blockchain can enhance traceability, supply chain management, and food safety by recording and verifying every stage of production, processing, and distribution.
- **h) Big data analytics:** Big data analytics involves analyzing large and complex data sets to derive meaningful insights. In agriculture, it aids in crop modeling, weather forecasting, market trends analysis, and supply chain optimization.
- **i) Drones:** Drones have gained widespread usage in agriculture, particularly in China where they are employed to survey vast areas of cotton crops covering millions of hectares. Drones provide valuable insights that may not be easily observable from the ground, aiding in determining optimal harvest timing, monitoring irrigation needs, implementing pest protection measures, and more.

A. IoT for Digital Agriculture:

The use of technology in agriculture has progressed greatly, and a number of new technologies indicate that farming has a bright future. Due to its widespread usage, the Internet of Things (IoT) has transitioned from an emergent technology to a common tool. The control of devices that may send data via a network via the internet is known as the Internet of Things.

The idea was first introduced by Kevin Ashton in 1999 when discussing RFID tags for supply chain management at Procter and Gamble. The first network-connected device was a vending machine at Carnegie Mellon University in 1982 (Cave 2012).

In 2000, LG Electronics introduced the Internet of Things (IoT)-capable Internet Digital DIOS refrigerator, which tracked food in storage using RFID tags and paved the way for other home appliances to be internet-connected.

The term "Internet of Things" gained popularity in 2008–2009, marking a turning point in technological advancement when there were more connected gadgets than people on the planet. IoT is now essential to agriculture, improving productivity and allowing for data-driven management decisions.

IoT technologies in agriculture have led to the development

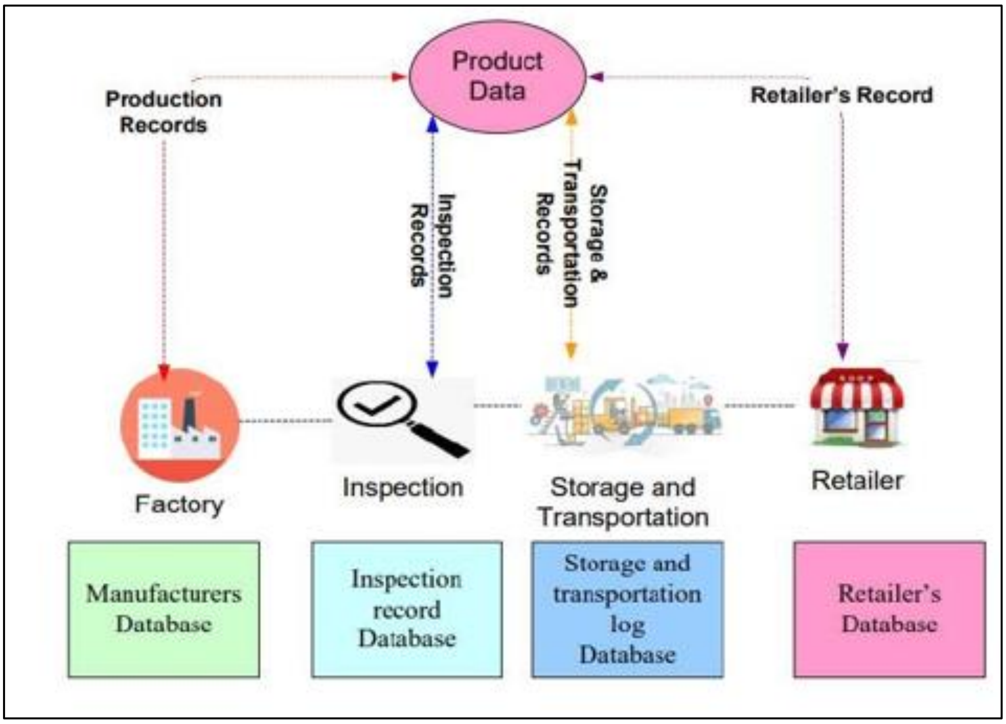

Figure 17.1: Practice of IoT in digital supply chain management (Source: Chauhan *et al.* 2022)

of smart agricultural solutions, enabling farmers to manage their fields remotely through sensors and automated irrigation systems. This technological advancement allows farmers and stakeholders to monitor field conditions from any location. IoT applications in agriculture cover a broad spectrum of solutions.

B. Role of Sensors in Digital Agriculture:

A sensor is a device that identifies and responds to certain inputs such as pressure, light, moisture, motion, heat etc., and transforms them into signals that humans can read for analysis and interpretation.

Different types of sensors could be used to interpret various discrepancies viz., electromagnetic sensors to assess the electrical conductivity of soil particles, optoelectronic sensors for various purposes, including measuring soil organic matter (SOM), soil moisture, and cation exchange capacity (CEC), electrochemical sensors to detect certain ions like nitrate, potassium, or hydrogen (for pH), ion selective electrode sensors are widely used to measure the potential of a particular ion in a solution and are often used to quantify the amount of nitrogen present in soil, mechanical sensors to measure the soil resistance, acoustic sensors provide information on soil texture, airflow sensors detect the permeability of air in the soil and dielectric soil moisture sensors to determine the moisture content of the soil (Dwevedi *et al*., 2017)

C. Role of Robotics in Digital Agriculture:

Robotics in agriculture increase agricultural productivity. Agribots, or agricultural robots, are a novel solution that has evolved in response to the growing global demand for agricultural products and labour shortages. Due to their ability to enhance farming practices and alleviate labour shortages, these cutting-edge machines are becoming more and more popular among farmers. Research and development are still ongoing for many Agribot products, which are currently in the testing stage (Gopal *et al*., 2021)

Weeding is one of Agribots primary uses. These smart robots compare photos of crops and weeds in their database using digital image processing, which enables them to recognise and effectively remove or spray weeds with robotic arms. The potential savings from weeding robots might amount to about 13,000 kilogrammes (3 billion pounds) less pesticide used per year, or about 1,725 crores ($25 billion) in savings.

Machine navigation is another area where IoT-driven automation in agriculture is changing how jobs like cultivation and ploughing are done. With GPS technology, farmers can operate tractors and heavy ploughing equipment remotely from the comfort of their homes. These intelligent, self-adjusting devices have a high degree of precision when negotiating different types of terrain.

Harvesting robotics has greatly reduced the labour-intensive process of gathering fruits and vegetables. Agribots that can harvest crops work nonstop, around the clock, filling the labour gap and streamlining the harvesting procedure. They can also be used in greenhouses, where they can precisely identify a crop's stage and harvest it at the right moment, which is advantageous for high-value crops like strawberries and tomatoes (Kaur *et al.,* 1993).

With robots working alongside humans in agriculture, physical labour duties may now be handled more effectively. These robots are capable of lifting large objects and carrying out precise tasks like plant spacing. This efficient material handling lowers manufacturing costs while increasing overall plant quality and optimising space utilisation.

D. Role of Precision Agriculture in Digital Agriculture:

Precision farming, also known as precision agriculture (PA), is a modern approach to managing agricultural operations by utilizing specific information regarding nutrient management, remote sensing, global information systems, global positioning systems, and variable rate application. Its goal is to effectively optimize the use of production inputs by performing the appropriate actions, in the correct locations, using the right methods, at the optimal times, and following the appropriate procedures. By carefully managing inputs such as water, seeds, and fertilizers, precision farming aims to enhance crop yield, quality, and profitability while minimizing waste and promoting environmental sustainability. The objective of precision farming is to align agricultural inputs and practices with the specific requirements of crops and agro-climatic conditions, thereby improving the precision and accuracy of their application (Roy and George 2020).

E. Remote Sensing in Digital Agriculture:

Data acquisition in farming areas has undergone a paradigm shift thanks to remote sensing. IoT-driven remote sensing uses weather stations and other strategically positioned sensors to collect vital data from farms. Then, for a comprehensive study, this data is sent to analytical tools. With the use of an analytical dashboard and these sensors, farmers can monitor crops and take informed action based on findings. The sensors' purpose is to detect anomalies. Crop monitoring to identify variations in light, humidity, temperature, form, and size is one of the many useful applications of remote sensing. It makes better crop growth supervision possible and helps spot diseases early on by identifying irregularities. Furthermore, the information gathered by sensors on meteorological parameters such as temperature, humidity, precipitation, and dew detection allow for more educated decision-making about the best growth techniques depending on current weather patterns. In addition, nutrient value, drier areas, soil drainage capacity, and acidity levels are all determined by soil health analysis. These findings help select the best cultivation techniques and optimise water use for irrigation. The data on soil health also helps to promote climate-smart agriculture, enhance soil structure, and encourage the use of regenerative agriculture techniques.

F. Satellite Imaginary in Digital Agriculture:

Remote agricultural area monitoring is made possible by satellite imaging, which also offers useful data on the amount of water required by various farms. This enhances irrigation planning and management effectiveness by enabling farmers to evaluate and identify the ideal water requirements for every plot. Farmers may avoid over- or under-irrigation and make well-informed decisions about water use by utilising satellite imagery analysis. This can save costs and result in higher quality crops and higher output. Satellite imagery also helps agriculture become more resilient to climate change. It enables farmers to keep an eye on weather patterns and forecast natural calamities like floods, droughts, or unexpected downpours. By preparing and taking preventive action to safeguard their crops, farmers can lessen the impact of extreme weather events on agriculture thanks to this early knowledge. satellite imagery supports the adoption of climate-resilient farming practices through its insights into fluctuating weather patterns.

The utilisation of satellite imagery is essential for attaining agricultural sustainability. Accurate yield estimations, precise pesticide usage, precision farming techniques, climate resilience, effective water management, and agricultural research and development are all made possible by it. Farmers and agribusinesses may maximise resource utilisation, boost productivity, and advance sustainable agricultural practices by utilising satellite imagery.

G. Role of Drones in Digital Agriculture:

Drones have been instrumental in transforming the agricultural industry by streamlining a number of farming tasks, including mapping, spraying, soil analysis, and crop monitoring. One of the main industries utilising drone technologies is agriculture. Drones with cameras and sensors are used to map, photograph, and survey farmlands. There are two types of drones: aerial drones, sometimes referred to as unmanned aerial vehicles (UAVs) or unmanned aircraft systems (UAS), are robots that fly, and ground-based drones that move across fields on wheels. These drones can be commanded remotely or programmed to fly on their own with the use of software-controlled flight plans that work with GPS and sensors.

The applications of drones in agriculture include:

Irrigation and water management: Farmers face difficulties with irrigation, but thermal camera-equipped drones may detect concerns such as insufficient or excessive moisture.

Crop surveying and mapping: Unlike the more expensive and imprecise satellite imagery utilised in the past, drones provide real-time and accurate footage, revolutionising crop mapping and monitoring.

Spraying management: Drones are a great tool for precision agriculture spraying because they are airborne tools. They collect data from agricultural regions and apply pesticides and fertiliser precisely where needed thanks to sensors attached to them. Drone sprayers eliminate the risks associated with hand spraying and provide superfine spray treatments, increasing efficiency and reducing pesticide costs.

Weeds and pest control management: Drones with sophisticated cameras, sensors, and GPS systems are used in precision agriculture to precisely track and control pests and weeds in a variety of crops. Drones provide fast weed and pest infestation detection by photographing fields while in the air (Talaviya *et al.*, 2020)

Soils inspection: In place of labour-intensive physical field visits and soil sample techniques, drones are frequently used to evaluate the state of the soil.

H. Farm Management System and Decision Support Tools for Digital Agriculture:

The term "farm management systems" (FMS) describes how cutting-edge tools, software, and procedures are combined to effectively manage agricultural activities. The entire farming process, from planning and planting to harvesting and marketing, is intended to be optimised by these systems. Farm management systems would benefit farmers, agricultural businesses, and the environment in many ways by utilising data-driven decision-making, automation, and real-time monitoring (Dinesh *et al.*, 2023).

A decision support tool for agriculture is a device or piece of software that assists farmers in making data-driven decisions to boost output and efficiency while also optimising resource allocation and efficacy. These systems frequently integrate data collected from a range of sources, including sensors, satellite imaging, weather forecasts, and historical records, to offer insights and recommendations for resource allocation, crop management, and other agricultural operations. Few instances of agricultural decision support tools in use are crop advisory and monitoring systems, Variable Rate Technology (VRT) Systems, Farm Management Software, Integrated Pest Management (IPM) Software, Market Analysis and Pricing tools

I. Big Data Analytics and Prediction Modeling in Digital Agriculture:

The term "big data" describes an enormous volume of both organised and unorganised data that may be analysed and investigated to create predictive algorithms that will help with decision-making. Big data is assisting in the solution of significant worldwide agricultural issues, including efficiency, safety, food security, and sustainability. Big data has expanded to include the entire food supply chain, not just agriculture. Several aspects of agriculture have benefited from the Internet of Things. We can create a more secure and sustainable food system for all by using this data to inform our decision-making. The primary data sources are transactions, operations, and pictures and videos that are gathered by robots and sensors. Effective analysis is where this data's real power lies, though. Applications for risk management, sensor utilisation, predictive modelling, and benchmarking can be developed thanks to big data. A thorough understanding of big data can address issues in conventional farming, leading to higher crop quality and productivity (Himesh *et al.*, 2018).

J. Role of Blockchain Technology for Digital Agriculture:

A rapidly growing and disruptive technology, blockchain is utilized to change established business models and open up new options for the whole supply chain. The term "blockchain" is widely used to describe a completely distributed digital system that keeps a permanent, linear recording of all transactions between networked actors. The purpose of blockchain technology is to facilitate payments in the virtual currency market. Blockchain applications are already quite powerful in financial services, but they have only just been expanded to operations and supply chain management.

17.2.3 Challenges in Digital Agriculture:

1. Lack of Digital Literacy: It's possible that a large number of farmers and agricultural laborers lack the digital literacy needed to make efficient use of and profit from technology. In order to assist farmers, make the most of digital tools, it is imperative to provide training and support.
2. Access to Reliable Internet: The adoption of digital technologies that depend on online connectivity is hampered in many rural regions by the absence of dependable, fast internet access.
3. Cost of Technology: For small-scale farmers with little funding, the initial outlay needed for digital technology like sensors, drones, and precision farming equipment can be a major obstacle.
4. Data Privacy and Security Concerns: Due to worries about data privacy and security, farmers may be hesitant to utilize digital technologies. Data breaches and misuse of sensitive information can erode trust in digital solutions.
5. Interoperability Issues: Some digital tools and platforms may struggle to integrate with current farm management systems or other technologies, complicating data sharing and integration.
6. Technological Complexity: Farmers might be discouraged from using technologies that are overly complex or difficult to operate. User-friendly and intuitive systems are crucial for successful adoption.

7. Sustainability and Long-Term Viability: Farmers may be reluctant to invest in digital technologies if they are unsure about the long-term benefits.
8. Infrastructure and Power Supply: In remote agricultural areas, the lack of necessary infrastructure, such as electricity, can impede the implementation of digital technologies that require a constant power supply.
9. Cultural and Behavioral Barriers: Traditional farming practices and deeply rooted cultural beliefs can sometimes resist the adoption of new technologies.
10. Limited Awareness and knowledge**:** It is possible that some farmers are ignorant of the possible advantages of digital technologies.

17.2.4 Policy and Regulatory Considerations for Digital Agriculture:

In September 2021, Mr. Narendra Singh Tomar, the Union Minister of Agriculture & Farmers Welfare, announced the launch of the Digital Agriculture Mission 2021–2025. To further the cause of digital agriculture through pilot projects, CISCO, Ninjacart, Jio Platforms Limited, ITC Limited, and NCDEX e-Markets Limited (NeML) signed five memorandums of understanding (MoUs). The goal of the mission is to promote and expedite initiatives that utilize emerging technologies, including artificial intelligence (AI), blockchain, remote sensing, geographic information systems (GIS), and the usage of robots and drones. To improve farming and knowledge exchange, Cisco created an Agricultural Digital Infrastructure (ADI) solution in August 2019.

This ADI is anticipated to be a key component of the Department of Agriculture's National Agri Stack data pool, which includes prototype projects in Morena (Madhya Pradesh) and Kaithal (Haryana). To empower farmers and digitize the agricultural ecosystem along the whole value chain, the Jio Agri (JioKrishi) platform was introduced in February 2020. While the platform's advanced functions collect data from several sources, feed it into AI/ML algorithms, and deliver accurate, individualized recommendations, the platform's primary function employs stand-alone application data to provide advisory services. This program will have its pilot initiatives in Jalna and Nashik (Maharashtra).

New developments and opportunities in agricultural digital technologies. In the more over 10,000 years since its start, agriculture has come a long way. Although our ancestors developed primitive techniques for the basic production of consumable plants, modern agricultural practices involve the careful application of a multitude of scientific theories and some of the most exciting technological developments accessible.

17.3 Conclusion:

This book chapter highlights the transformative role of digital technology in agriculture, driving innovation across the industry. Adopting digital solutions leads to enhanced communication, efficient monitoring, and informed decision-making, resulting in cost and time savings and improved operational efficiency. Technological advancements like precision agriculture, artificial intelligence, IoT, robotics, and blockchain are explored. While challenges persist in leaf-level disease detection, the canopy-based approach using UAVs equipped with spectral cameras shows promise.

Embracing digital agriculture is vital for achieving food self-sufficiency, elevating food and fiber quality, and promoting environmental sustainability. These innovations offer a path to a resilient and prosperous future for global agriculture.

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