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From Seed to Screen: Digital Transformation in Vegetable Farming

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The digital revolution is reshaping every sector of the global economy, and agriculture is no exception. Vegetable farming, characterized by its high-value crops, intensive management, and sensitivity to environmental changes, has become one of the primary beneficiaries of digital innovation. Technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), drones, remote sensing, cloud computing, mobile applications, and precision farming tools are transforming traditional cultivation into a data-driven and intelligent production system. These technologies enable farmers to monitor crop health, optimize irrigation and fertilizer use, detect pests and diseases at an early stage, and access real-time weather forecasts and market information. Digital platforms also bridge the gap between producers and consumers by improving supply chain management and reducing post-harvest losses. Although challenges such as limited digital literacy, inadequate infrastructure, and high investment costs remain, continuous technological advancements and government initiatives are accelerating the adoption of digital agriculture. Digital transformation is not merely introducing new gadgets into farming—it is changing the way decisions are made, improving sustainability, enhancing profitability, and ensuring food security. This article discusses the major digital technologies revolutionizing vegetable farming, their applications, benefits, challenges, and future prospects.

Keywords: Digital agriculture, Precision farming, Smart farming, Internet of Things (IoT), Artificial Intelligence, Vegetable production, Remote sensing, Drones, ICT, Sustainable agriculture

Introduction

Vegetables are indispensable components of a balanced diet and contribute significantly to human nutrition by supplying vitamins, minerals, antioxidants, dietary fiber, and health-promoting phytochemicals. They are also among the most profitable crops cultivated by farmers because of their high market value and increasing consumer demand. However, vegetable cultivation is highly intensive and requires continuous monitoring, timely irrigation, balanced nutrient management, pest and disease control, and efficient post-harvest handling. Traditional farming practices rely largely on farmers' experience and manual observation. While these methods have sustained agriculture for generations, they often result in inefficient use of water, fertilizers, pesticides, and labor. In addition, climate change, erratic rainfall, rising temperatures, labor shortages, and fluctuating market prices have increased risks associated with vegetable production. The emergence of digital technologies is changing this scenario. Digital agriculture combines information technology with agricultural science to provide farmers with accurate, timely, and location-specific information. Instead of depending solely on intuition, farmers can now make scientific decisions based on real-time data collected from their fields. This transformation—from seed selection to harvesting and marketing is often referred to as journey "From Seed to Screen."

What is Digital Agriculture?

Digital agriculture refers to the application of modern digital technologies to improve agricultural production, farm management, and marketing. It integrates sensors, communication technologies, satellite imagery, artificial intelligence, cloud computing, robotics, and data analytics to support decision-making throughout the crop production cycle. Unlike conventional farming, where management practices are applied uniformly across the entire field, digital agriculture enables site-specific management. Every section of a field can be monitored individually, allowing farmers to provide the right input at the right place and at the right time.

Major Digital Technologies Used in Vegetable Farming

Internet of Things (IoT)

The Internet of Things is one of the most important innovations in modern agriculture. IoT involves connecting sensors and devices through the internet to collect and transmit field information continuously. Soil moisture sensors indicate when irrigation is needed, preventing both overwatering and water stress. Temperature and humidity sensors help monitor environmental conditions inside polyhouses and greenhouses, while nutrient sensors estimate the availability of essential elements in the soil. For example, in tomato cultivation, IoT-based irrigation systems automatically supply water whenever soil moisture falls below the optimum level. This not only conserves water but also improves crop growth and fruit quality.

Artificial Intelligence (AI) and Machine Learning

Artificial Intelligence has transformed agricultural decision-making by analyzing large volumes of data collected from farms. AI-powered mobile applications can identify diseases simply by analyzing photographs of infected leaves. Farmers receive instant recommendations regarding the nature of the disease and suitable control measures. Machine learning algorithms also predict pest outbreaks, estimate crop yield, and recommend the most appropriate planting dates based on historical weather data and current climatic conditions. AI is increasingly being integrated into digital agriculture to improve productivity and resource efficiency.

Drone Technology

Drones, also called Unmanned Aerial Vehicles (UAVs), are becoming valuable tools in vegetable production. They capture high-resolution images of crop fields, helping farmers identify nutrient deficiencies, water stress, weed infestation, and disease symptoms before they become visible to the naked eye. Modern drones are also used for precision pesticide spraying, ensuring uniform chemical application while reducing labor costs and minimizing environmental pollution. Because vegetables often require frequent crop protection measures, drone technology significantly improves operational efficiency.

Remote Sensing and GIS

Remote sensing uses satellite or aerial imagery to monitor crop performance over large areas. Geographic Information Systems (GIS) combine these images with geographical data to create detailed maps showing crop growth, soil variability, and moisture distribution. These technologies help farmers identify problem areas within fields, estimate crop growth stages, and make informed management decisions. Instead of applying fertilizers uniformly, farmers can apply them only where required, reducing unnecessary expenditure.

Precision Farming

Precision farming refers to managing crop production based on field variability rather than treating the entire farm equally. GPS-guided machinery, variable-rate fertilizer applicators, automated irrigation systems, and yield mapping technologies allow farmers to optimize input use while maintaining maximum productivity. In vegetable farming, precision agriculture is especially valuable because vegetables respond quickly to changes in nutrient availability and irrigation.

Mobile Applications and Digital Advisory Services

Smartphones have become powerful agricultural tools. Today, farmers can access weather forecasts, fertilizer recommendations, pest alerts, government schemes, and market prices through mobile applications. Digital advisory platforms provide personalized recommendations based on crop type, location, and growth stage. Many countries are also promoting digital extension services where farmers can directly interact with agricultural scientists through mobile applications and online portals. These services reduce the gap between research institutions and farming communities.

Digital Transformation Across the Vegetable Value Chain

Digital technology influences every stage of vegetable production. **Before planting**, farmers use weather forecasts, soil testing reports, and digital advisory services to select suitable crops and varieties. **During crop growth**, IoT sensors continuously monitor soil and environmental conditions. AI-based systems recommend irrigation schedules, fertilizer doses, and pest management practices. **At harvest**, digital tools estimate maturity and yield, enabling better planning. **After harvest**, digital supply chain management systems help reduce losses during storage and transportation. Farmers can sell produce through online marketplaces, ensuring better price realization and improved market access. Thus, digital transformation extends beyond crop production to include the entire agricultural value chain.

Advantages of Digital Vegetable Farming

Digital agriculture offers numerous benefits. It increases productivity by enabling timely management decisions. Early detection of diseases reduces crop losses and lowers pesticide consumption. Precision irrigation improves water-use efficiency, which is particularly important in regions experiencing water scarcity. Digital technologies also reduce production costs by optimizing fertilizer, pesticide, and labor use. Better weather forecasting minimizes climate-related risks, while online marketing platforms improve farmers' bargaining power and increase income. Moreover, digital agriculture supports environmentally sustainable farming by reducing greenhouse gas emissions, conserving natural resources, and minimizing chemical contamination.

Challenges in Adoption

Despite its enormous potential, several constraints limit the widespread adoption of digital agriculture. Many small and marginal farmers cannot afford expensive sensors, drones, and precision farming equipment. Limited internet connectivity in rural areas further restricts the use of digital technologies. Digital literacy also remains a significant challenge. Many farmers require training to effectively use smartphones, mobile applications, and digital advisory services. Data privacy, cybersecurity, equipment maintenance, and the lack of locally customized digital solutions are additional concerns that need attention.

Government Initiatives Supporting Digital Agriculture

Governments across the world are promoting digital agriculture through various initiatives. In India, programs under the Digital Agriculture Mission encourage the use of digital technologies, artificial intelligence, geospatial tools, and digital public infrastructure to improve agricultural productivity and farmer services. FAO also promotes digital agriculture through Smart Farming and Digital Villages initiatives that improve access to digital tools and knowledge for farmers.

Future Prospects

The future of vegetable farming will be increasingly technology-driven. Artificial intelligence will become more accurate in predicting diseases and recommending crop management practices. Agricultural robots may perform transplanting, harvesting, and grading operations with minimal human intervention. Blockchain technology will improve food traceability, enabling consumers to track vegetables from farm to market. Digital twins, cloud-based farm management systems, and advanced robotics are expected to make farming more precise,

efficient, and profitable. As digital infrastructure expands and technology becomes more affordable, even smallholder farmers will benefit from these innovations.

Conclusion

Digital transformation is revolutionizing vegetable farming by integrating science, technology, and data-driven decision-making into every stage of crop production. From selecting quality seeds to monitoring crop growth through sensors, predicting diseases using artificial intelligence, and marketing produce through digital platforms, technology is reshaping agriculture like never before. Although challenges such as infrastructure, affordability, and digital literacy remain, the long-term benefits far outweigh the limitations. Digital agriculture enhances productivity, conserves natural resources, improves farmers' incomes, and contributes to sustainable food production. The journey from "**Seed to Screen**" represents not only technological advancement but also a new era of smart, resilient, and sustainable vegetable farming.

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