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Role of Agricultural Extension in Advancing Digital Agriculture and Smart Farming

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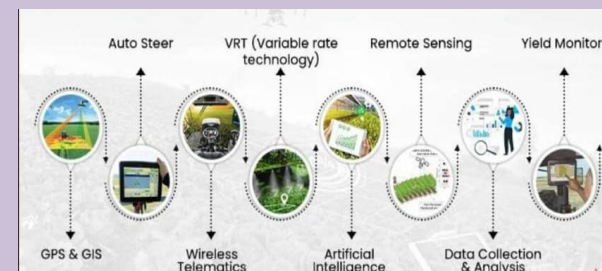
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INTRODUCTION

Agriculture is experiencing a digital revolution. The convergence of Artificial Intelligence (AI), Internet of Things (IoT), remote sensing, drones, Geographic Information Systems (GIS), big data analytics, robotics, and mobile-based applications is transforming the agricultural production system at the global level. And this system transformation—often termed Digital Agriculture, or Smart Farming is intended to enhance productivity and profit, resource-use efficiency, and environmental sustainability. Yet the effective uptake of these technologies is largely dependent upon the knowledge, skills and information access of farmers. Agricultural Extension contributes significantly in narrowing the distance between science and technology with farming communities. Extension services contribute to knowledge exchange, build farmers' capacities and ensure that digital technologies are leveraged to support agricultural development.

Understanding Digital Agriculture and Smart Farming

Digital Agriculture is the use of digital technologies, data analytics, and information systems across the agricultural value chain. It allows farmers to make better decisions based on scientific recommendations and real-time data. Smart Farming is the use of contemporary technology to observe, control and manage agricultural processes more precisely and efficiently. Smart farming uses automated machinery, sensors, digital platforms and data-based decision making to enhance farming.



Major Technologies Used in Digital Agriculture

Digital agriculture uses a wide range of advanced technologies to improve farm management, productivity, and decision-making. Major technologies include artificial intelligence (AI), the Internet of Things (IoT), Geographic Information Systems (GIS), Global Positioning Systems (GPS), remote sensing, drones and unmanned aerial vehicles (UAVs), big data analytics, robotics and automation, mobile applications, digital platforms, and cloud computing. Together, these technologies enable real-time monitoring, precise input application, efficient resource management, automated farm operations, and timely advisory services.

Benefits of Digital Agriculture

Digital agriculture enhances crop productivity and profitability through efficient utilization of water, fertilizers and pesticides. It allows for more efficient pest and disease control, lower production costs, increased climate resilience and improved access to market information, contributing to more sustainable and better-informed farm management decisions.

Agricultural Extension: A Bridge between Technology and Farmers

Agricultural Extension is a non-formal educational process concerned with application of scientific research and new knowledge to agricultural practices

that farmers can use to increase their productivity and livelihoods. In the age of digital agriculture, extension professionals act as facilitators, educators, communicators, and innovators. The linkages between researchers, technology developers, policy makers, private organizations and farmers are established through extension systems and the end result is that farmers receive the fruits of technological innovation.



Major Roles of Agricultural Extension in Advancing Digital Agriculture

Extension services also play an important role in promoting digital agriculture by reaching farmers with cutting-edge technologies including mobile applications, sensors, drones, and tools for precision agriculture. It builds the skills of the farmers through training, demonstrations and on farm lessons while empowering digital literacy and technology adaptation. Extension services have also been offering real-time advice on crop management, irrigation, nutrients application, pest control and weather forecasting using digital platforms. In addition,

extension serves as a bridge among farmers, researchers, agri-tech companies and policy makers to facilitate innovation, collaboration and iterative refinement of technologies using farmer feedback and problem-solving sessions.

Digital Tools Used in Agricultural Extension

Contemporary agriculture extension employs Information and Communication Technologies (ICTs) including mobile applications, SMS/voice advisory services, social media platforms, artificial intelligence, remote sensing, drones, IoT devices, and online learning platforms to provide agriculture information in a timely and precise manner. Crop and nutrient management, pest and disease identification, weather prediction, market knowledge, precision agriculture, and real-time decision making are all supported by these digital technologies, as are farmer learning, communication, and admission to extension services.



Benefits of Digital Extension Services

Among the benefits of digital extension services are faster delivery of information, greater access to farmers in the remote areas, reduction in extension costs and enhanced communication efficiency. They allow real-time advisory services, improve farmer

participation and monitoring and evaluating, and facilitate technology adoption. The availability of timely and relevant information at the farmers' fingertips is widely assumed to contribute to better decision making, higher productivity, and better management of farms through digital extension services.

Challenges in Digital Agriculture and Extension Farmer-Related Challenges

- Poor digital literacy levels
- Lack of knowledge about technologies
- Resistance to taking up new innovations
- Tiny and fragmented landholdings.

Infrastructure Challenges

- Bad internet connection
- Smartphones and digital devices are not easily available
- Unavailability of power supply in the villages.

Institutional Challenges

- Extension personnel were not adequately trained
- Resource constraint are quite severe
- There is poor coordination among stakeholders
- Inadequate policy support.

Technological Challenges

- High cost of advanced technologies
- Data privacy concerns
- Lack of location-specific digital solutions

Strategies for Strengthening Digital Extension

To promote the effectiveness of extension in digital agriculture, farmers' digital literacy and extension

staff training in new technologies should be enhanced. Easy to use mobile applications should be developed in the local language with the support of enhanced rural digital infrastructure and the provision of reliable internet connectivity. Promote also public-private partnerships, digital knowledge centres, smart villages, FPOs and co-operative models among others. In addition, start-up ecosystems and incubation centres should be promoted to drive innovation, and inclusive policies need to be crafted to ensure that the benefits of digital agriculture percolate to all farm communities.

Future Perspectives

The future of extension will be more digital, data-driven and focused on the farmer. Technologies like artificial intelligence, machine learning, blockchain, robotics, autonomous machinery and digital twins are also anticipated to revolutionize agricultural advisory services. The future extension system will focus on personalized advisories, climate smart agriculture, precision resource use, real time monitoring and forecasting, integrated digital farming platforms, and sustainable and resilient agricultural systems. And agricultural extension professionals will have an important role in continuing to ensure that farmers use these technologies effectively and realize the greatest benefits.

CONCLUSION

Agricultural Extension contributes significantly for the promotion of digital agriculture and smart farming. Through technology transfer, capacity building, digital literacy enhancement, provision of advisory services and facilitation of collaboration among stakeholders, extension systems make it possible for farmers to take up new technologies and

improve agricultural productivity. Enhancing digital extension services will be key to sustainable agricultural development, food security, and climate-resilient farming systems in the coming era.