

Digitalization in agriculture

for innovative transformation in India

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Digitalization in agriculture has a great potential to bring about significant innovation and transformation in India's agricultural sector. The adoption of digital technologies can help India to increase agricultural productivity, reduce waste, increase agricultural export, increase farmers' income and improve food and nutrition security. Apart from this, this will help in protecting environment and sustainable development of overall agricultural sector. The increase in internet and mobile phone penetration in India has had a significant impact on various sectors, including agriculture, education, healthcare, and e-commerce. This clearly shows that now Indian agricultural is ready for digital transformation.

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It can be seen that growth and penetration of digital infrastructure in India is quite high. India has the world's second-largest mobile phone market, with 1.2 billion mobile phone subscribers as of December 2021. The internet penetration in rural India is 41% as opposed to 71% in the cities and towns. The study estimates that India will be home to 900 million net users by the end of 2025 and that 56% of the 141 million new netizens will be from rural India. The digitalization of agriculture can drive innovation and transformation in broadly four sectors of Indian agriculture, viz. (i) Precision agriculture, (ii) Climate-smart agriculture, (iii) Supply chain management, and (iv) Financial inclusion.

Precision agriculture

In this digital technologies are being used such as sensors, drones and satellite imagery. Using digital equipment, tools, software, process, farmers can monitor their crops, orchards, animals, aquaculture systems, soil, water, weather, post-production management of produce in real-time, enabling them to make more informed decisions about planting, irrigation, fertilization, pest management, harvest and post-harvest management of agricultural produce. This can help to reduce waste, improve yields and quality, and save costs. Briefs about some major precision agriculture digital technologies are given as:

Applications of sensors in agriculture: Sensors are being increasingly used in Indian agriculture to

improve productivity, reduce waste and optimize resource use. Soil moisture sensors are used to measure real-time soil moisture levels, to optimize the irrigation practices. Nutrient sensors can provide real-time data to optimize fertilization practices. Weather sensors can provide real-time data on weather conditions. Crop health sensors are used to monitor the health and growth of crops. Sensor-based post-harvest management by using temperature sensors, humidity sensors, ethylene sensors and quality sensors of agricultural produce can help to reduce post-harvest losses, improve quality, and increase profitability for farmers. While monitoring quality, farmers can identify potential issues and take corrective action before the produce is shipped to market. GPS sensors can be used to track the location of harvested produce during transportation, enabling farmers to monitor temperature, humidity, and other factors that can impact quality. Further, sensor-based storage management is an effective method of post-harvest management that can help Indian farmers to increase their productivity and income, reduce post-harvest losses, and improve the quality of their produce. This can increase consumer confidence in the produce and help to build a brand reputation for quality. However, it is important to ensure that these technologies are accessible and affordable to small-scale and marginalized farmers, who may not have the resources to invest in such technologies. This may

require government support in the form of subsidies, training programme, and infrastructure investments.

Variable rate technology (VRT): Variable Rate Technology (VRT) is a precision agriculture practice that involves the use of technology to apply different amounts of inputs (e.g. seed, fertilizer, water, pesticides, feed, chemicals) to different parts of a field, orchards, or any agricultural production system including livestock and fisheries, based on the specific needs. The use of VRT in agriculture can help to improve productivity, reduce input costs and minimize environmental impact. However, it is important to ensure that cost of these technologies are reduced to make it accessible and affordable to small-scale and marginalized farmers.

Drones: Drones, or unmanned aerial vehicles (UAVs), have become increasingly popular in agriculture due to their ability to collect data quickly and efficiently of an object without physical contact with object. Major applications of drones in agriculture are crop monitoring with high-resolution cameras, create detailed maps of agricultural land, soil quality, topography, and drainage patterns. spray crops with precise applications of pesticides and fertilizers, using in conjunction with other precision agriculture technologies, assess crop damage caused by natural disasters, monitor the water health and ecological conditions including fish health and biomass. However, it is important to ensure that drones are used safely and responsibly, and that farmers are trained in their use. Additionally, regulations around the use of drones in agriculture should be put in place to ensure that they are used legally and ethically.

Robotics: Robotics is the field of technology that involves the design, construction and operation of robots. In recent years, robotics has been increasingly used in agriculture to improve efficiency, reduce labour costs and increase productivity. Robots can be successfully employed for harvesting crops such as fruits and vegetables which can increase efficiency and reduce labour costs. For example, robotic arms can be used to pick fruits and vegetables, planting and seeding with precision to detect and remove weeds, water crops with precision, spraying chemicals which are dangerous to human health. Overall, robotics has the potential to revolutionize agriculture in India by increasing efficiency, reducing labour costs and improving productivity. However, the use of robotics in agriculture requires significant investment in technology, research, and development. Additionally, farmers and farm workers must be trained in the use of robotics technology to ensure that it is used effectively.

Artificial intelligence (AI): Artificial Intelligence (AI) has the potential to revolutionize Indian agriculture by enabling farmers to make data-driven decisions and optimize their crop yields. It can be effectively used for (i) predictive analytics, (ii) precision agriculture, (iii) pest and disease management, (iv) soil health management, (v) livestock herd management and dairy automation, (vi) aquaculture automation and management (vii) market prediction. In case of predictive analytics, AI can be used to analyse historical weather data and crop

data to make predictions about future crop yields. This can help farmers to plan their planting and harvesting schedules and optimize their crop management practices. AI helps to identify pests and diseases early on and recommend appropriate treatment options. This can help farmers to minimize crop losses and reduce the need for chemical treatments. AI can be used to analyse soil data and provide recommendations for optimizing soil health. This can help farmers to reduce soil erosion, improve water retention and increase crop yields.

Protected cultivation: Protected cultivation is the practice of growing crops under a controlled environment using structures such as greenhouses, shade net houses and polyhouses. This method of cultivation has become increasingly popular in Indian agriculture due to its ability to protect crops from adverse weather conditions, pests, and diseases. This reduces the cost of crop management and improves the quality of the crops. This is particularly beneficial for high-value crops such as vegetables and fruits, which require high-quality produce to fetch better prices in the market. The protected cultivation is an effective method of cultivation that can help Indian farmers to increase their productivity and income. However, it is important to ensure that the structures used for protected cultivation are sustainable and do not have adverse effects on the environment. Additionally, farmers should be trained in the use of protected cultivation techniques to ensure that they are used effectively.

Vertical Farming: Vertical farming is a method of growing crops in vertically stacked layers using artificial lighting and a controlled environment. This method of cultivation has become increasingly popular in Indian agriculture due to its ability to produce high yields of crops in a small space with minimal environmental impact. Apart from the benefits of protected cultivation it has efficient use of space i.e. vertical farming allows farmers to grow crops in a small space, making it ideal for urban agriculture and areas with limited land availability. This can help to increase the productivity of agriculture in cities and reduce the carbon footprint of transporting food from rural areas. It can be seen that vertical farming is an effective method of cultivation that can help Indian farmers to increase their productivity and income, particularly in urban areas.

Aquaponics and hydroponics: Aquaponics and hydroponics are two modern methods of cultivation that have become increasingly popular in recent years. Both methods involve growing plants without soil, using water as the primary growing medium. Aquaponics is a method of cultivation that combines aquaculture and hydroponics. In this method, fish are grown in tanks, and the waste produced by the fish is used to fertilize the plants grown hydroponically, whereas, Hydroponics is a method of cultivation that involves growing plants in a nutrient-rich solution without soil. The nutrients supplied by the fish waste help to produce high-quality crops, making aquaponics ideal for high-value crops such as herbs and leafy vegetables, whereas, in case of hydroponics we apply highly reduced

chemical pesticides and herbicides. The aquaponics and hydroponics are effective methods of cultivation that can help Indian farmers to increase their productivity and income, particularly in urban areas or areas with water scarcity.

ICAR initiatives

Indian Council of Agricultural Research (ICAR) initiated a network program in the field of precision agriculture named as “ICAR- Network Program on Precision Agriculture (NePPA)”. This was initiated by the council initially with 16 ICAR research institutes with IARI as lead. The programme is focused on exploring potential applications of recent developments on technologies related to sensor, IoTs, drone and ICTs for precision smart agriculture. The major objectives span its scope over soil fertility, crop health, livestock, post-harvest operations, aquaculture and upscaling these using advanced technologies like drones, variable rate technologies (VRT's) to enhance input use efficiency and optimal production system. Following are the major achievements under this programme:

- **Development of spectral models for quick assessment of different soil attributes:** Models were developed using machine learning (ML) algorithms such as K-Nearest Neighbour (KNN), Random Forest (RF), Ridge Regression (RIDGE), Quantile regression forests (QRF), Least Absolute Shrinkage and Selection Operator (LASSO), Support Vector Machine (SVM) and Elastic Net (EN). The models were validated and compared, and the best pipeline was selected for assessment of different soil attributes.
- **Development of in-house drone:** Multirotor quadcopter design for agriculture health monitoring and surveying has been developed as part of project. It includes features like, real-time telemetry demonstration at any specified location, full HD live video transmission with dual camera support, all in one hand-held ground station for flying and mission planning. It has a payload capacity of 1.5 kg with a flight time of 40 to 45 minutes (without payload) and has the altitude capability of 120 m.



In-house drone

- **Development of IoT enabled irrigation scheduling system for field crops:** IoT (Internet of Things) based Irrigation Water Management System (IWMS) was developed and tested in wheat and chickpea to

measure the soil moisture at three different depths, viz. 20 cm, 40 cm and 60 cm. The mobile application pertaining to the irrigation scheduling was also developed in python and is under testing and subsequent debugging



Irrigation water management system

Digital agricultural knowledge dissemination system

Agricultural knowledge dissemination systems are important for providing Indian farmers with the information they need to make informed decisions about their farming practices. Digital technologies can play an important role in improving the efficiency and effectiveness of these systems. In India, following systems are already being implemented by different organizations responsible for the same:

- **Mobile-based applications:** Mobile applications can be developed to provide farmers with information on crop management practices, weather forecasts, market prices, and other relevant information. These applications can be designed to be user-friendly and accessible even for farmers with low literacy levels.
- **Interactive voice response (IVR) systems:** IVR systems can be used to provide farmers with information on demand, using a telephone. This can be useful for farmers who do not have access to smartphones or the internet. IVR systems can also be designed to provide personalized recommendations based on the specific needs of each farmer.
- **Digital kiosks:** Digital kiosks can be set up in rural areas to provide farmers with access to information on crop management practices, weather forecasts, market prices and other relevant information. These kiosks can be staffed by trained personnel who can assist farmers with accessing and interpreting information.
- **Farmer helplines:** Farmer helplines can be set up to provide farmers with advice and support on a wide range of issues related to agriculture. These helplines can be staffed by trained agronomists and other agricultural experts who can provide personalized recommendations based on the specific needs of each farmer.
- **Social media:** Social media platforms such as Facebook and WhatsApp can be used to disseminate agricultural information to farmers. Farmers can join groups and communities on these platforms where they can share information and advice with each other, as well as receive updates on new agricultural practices and technologies.

Indian Council of Agricultural Research (ICAR) developed a digital platform for agricultural extension system named as *KISAN SARATHI*-System of Agri-information Resources Auto-transmission and Technology Hub Interface. This has been developed to support this emerging need of multi ways and multilingual communication among various agricultural stakeholders. The ultimate goal of this project is to implement an intelligent online platform for supporting agriculture at local niche with national perspective. A total of 731 KVKs are enrolled with the system, where more than 3,600 agricultural scientists and subject matter experts are registered with *Kisan Sarathi*. The services of *Kisan Sarathi* for the farmers is available through an IVR based calling system via toll free numbers 1800-123-2175 and a short number 14426. More than 65 Lacs farmers are registered on this portal.

Climate smart agriculture

Digitalization is rapidly transforming the agriculture sector, and climate-smart agriculture (CSA) is no exception. Digital technologies can help farmers make better decisions, increase productivity and reduce the environmental impact of agriculture. Some of the important area of digitalization related to above field are weather monitoring and forecasting, precision farming, crop management, market access, data management, and farm management. Digitalization in CSA is still in its early stages, and there are challenges to overcome, such as the digital divide in rural areas and the cost of technology. However, the potential benefits are significant, and digitalization can play a vital role in making agriculture more sustainable and resilient in the face of climate change.

Supply chain management

Digitalization is transforming supply chain management in agriculture by improving transparency, traceability and efficiency. There are number of ways by which digitalization is quite beneficial for supply chain management in the field of agriculture. Digital technologies can capture and store data at the farm level, such as crop yields, soil health, and pesticide use. This information can help supply chain managers better understand the origin and quality of the produce they are sourcing. However, there are challenges to overcome, such as the cost of technology and the need for standardization across the industry. Nonetheless, the potential benefits of digitalization in agriculture supply chain management are significant, and it is an area that is likely to see continued growth and innovation in the years to come.

Financial inclusion

It is well known that digitalization is a powerful tool for promoting financial inclusion in agriculture, particularly in developing countries where smallholder farmers often lack access to formal financial services. Success of Unified Payment Interface (UPI) which is a fast payment system, used largely for peer-to-peer

payments and is also the most popular peer-to-merchant retail payment system in India with monthly transaction volumes of 8 billion in December 2022 (NPCI 2022) is quite motivational for adoption of digital platform of financial inclusion agriculture. Digital technologies such as mobile banking can help farmers access financial services such as savings accounts, credit and insurance. This can reduce the cost and complexity of accessing financial services, making it easier for smallholder farmers to participate in the formal economy. Digital platforms can facilitate payments between farmers, buyers, and financial institutions. Digital tools can facilitate communication and record-keeping within groups, making them more efficient and transparent. Further, these tools can provide farmers with access to financial education and training, enabling them to make informed decisions about financial management and investment. Digitalization is transforming the financial landscape of agriculture, and the potential benefits for smallholder farmers are significant.

G20 perspective

The G20 is a forum of the world's largest economies, including both developed and developing countries. Digital agriculture is an area of growing importance in the G20, as it has the potential to improve the sustainability, productivity and profitability of agriculture. The G20 has recognized the importance of digital agriculture and included it in its agenda. In 2018, the G20 Agricultural Ministers' Meeting in Buenos Aires, Argentina, discussed the role of digital agriculture in sustainable food systems and agreed to develop a roadmap for the adoption of digital technologies in agriculture. G20 has identified several priority areas for digital agriculture, including (i) Digital infrastructure: The G20 recognizes the importance of digital infrastructure, such as broadband connectivity and data centres, in enabling the adoption of digital technologies in agriculture. The G20 is working to improve digital infrastructure in rural areas and to address the digital divide between urban and rural areas, (ii) Data governance: The G20 is working to develop frameworks for data governance in agriculture, including data privacy and security, to ensure that digital technologies are used responsibly and ethically, (iii) Standards and interoperability: The G20 is working to develop standards and interoperability frameworks for digital agriculture to ensure that different technologies can work together to promote the development of open data platforms, (iv) Capacity building: The G20 is working to improve capacity building in digital agriculture, including training for farmers and extension workers, to ensure that they have the skills and knowledge to adopt and use digital technologies effectively and (v) Financing: The G20 recognizes the importance of financing for the adoption of digital technologies in agriculture and is working to increase investment in digital infrastructure and technologies. During G20 presidency held in Indonesia in 2022, G20 Policy Framework for an Equitable and Environmentally Sustainable Transition for digitalization of agriculture

has been discussed extensively. In G20 Meeting of Agricultural Chief Scientists (MACS) in Varanasi recently during the presidency of India, deliberations were held on Digital Agriculture and Sustainable Agri Value Chain and Public-Private Partnership. Digital agriculture is an area of growing importance in the G20, and there is a growing recognition of the potential benefits of digital technologies in agriculture. The G20 is working to promote the adoption of digital technologies in agriculture and to address the challenges and barriers to adoption.

Challenges in adoption

The major challenges in adoption of these technologies are:

- Extent of profitability should be beyond of a threshold through in usage of the technology;
- Amount of uncertainty and risk involved in adopting a technology including cost of the technology;
- Availability and suitability of technology in the agricultural production cycle;
- Requirement of skills and learning curve for adoption of the technology;
- Eco-environment and digital infrastructure

availability in a particular region;

- Level of agricultural production system;
- Ease of flow of agricultural credits, and
- Overall policy support for promotion of a technology.

SUMMARY

There is an increasing use of electronic extension services and social media in developing countries to share planting advice, weather updates, early disaster warnings and pest outbreak. Studies shows that technologies are being adopted separately and integrated and packaged together to address the specific problems of agricultural production. It was also reported that rate of adoption of Global Navigation Satellite System (GNSS) was highest in the US, UK, Australia and Denmark, with rates as high as 60% in the US and 77% in Australia. It was also found that adoption rates were substantially higher for machine guidance technologies than for VRT in all countries. Rates of adoption were higher for larger farms compared to smaller farms.

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