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DIGITAL FARMING: A PATHWAY TO SUSTAINABLE DEVELOPMENT IN INDIA

Agriculture

Deepa Abraham Assistant Professor, Department of Economics, Newman College, Thodupuzha, Kerala, India.

ABSTRACT

Digital farming is a revolutionary movement in the agricultural industry that integrates cutting-edge technologies to improve sustainability, efficiency and output. Digital farming is becoming a crucial answer as the globe struggles with issues like demographic explosion, climate change and the need for sustainable resource management. Sensor technologies, which offer real-time data on crop health, temperature, humidity and soil moisture, are important elements of digital farming. High-resolution photos are provided by drones and satellite imaging, which can be used to monitor agricultural conditions and spot pest infestations. Such collected data are analyzed by big data analytics and AI, which forecast results and suggest the best farming techniques. By combining these technologies, farm management software provides a single platform for organizing, observing and maximizing agricultural operations. Digital farming has advantages, but it also has drawbacks like upfront cost, worries about data security and privacy, the requirement for technical know-how and training. Thus, the paper is an attempt to examine various facets of digital farming, including its elements, advantages, difficulties and crucial role in advancing sustainable development. To conclude, digital farming presents a viable route for sustainable development with reduced their environmental impact, increased productivity and improved resource management by utilizing cutting-edge technologies.

KEYWORDS

Digital Farming, Sustainable Development, Agricultural Sector

INTRODUCTION

Since agriculture provides the basic materials required for both life and economic prosperity, it has always been a cornerstone of human society (Bhargava and Srivastava, 2019). However, the demands of a growing global population, climate change and the requirement for sustainable resource management are increasingly posing a threat to traditional farming methods (Giller *et al.,* 2021). As a reaction to these difficulties, digital farming has surfaced as a revolutionary strategy that makes use of contemporary technology to improve agricultural sustainability, efficiency and productivity (Abiri *et al.,* 2023). Precision farming, smart farming or digital farming are terms used to describe the application of cutting-edge technologies to farming methods. Drones, satellite photography, artificial intelligence (AI), machine learning, big data analytics and the Internet of Things (IoT) are some of these technologies where all these aims to maximize resource use, boost agricultural yields, lessen environmental effect and enhance overall farming operations efficiency (Shang *et al.,* 2021). At its core, digital farming relies on the collection and analysis of vast amounts of data. Sensors placed in fields, machinery and livestock monitor various parameters such as soil moisture, temperature, humidity, crop health and animal behaviour. This data is then processed using advanced analytics to provide actionable insights, enable farmers to make informed decisions, resulting in improved resource management, higher crop yields and reduced environmental impact. Thus, the paper is an attempt to examine various facets of digital farming, including its elements, advantages, difficulties and crucial role in advancing sustainable development.

The agri-food industry continues to be vital for jobs and means of subsistence. Globally, there are more than 570 million smallholder farms (Lowder *et al.,* 2016) and 28% of all workers are employed in agriculture and food production (ILOSTAT, 2019). More productive, efficient, sustainable, inclusive, transparent and resilient food systems are needed if the UN Sustainable Development Goal of a "world with zero hunger" is to be met by 2030 (FAO, 2017). The existing agrifood system will need to be drastically changed in order to achieve the targets. Technologies and advancements in the digital realm might contribute to the answer. Blockchain, the Internet of Things, artificial intelligence, and virtual reality are just a few of the "disruptive" digital technologies that are rapidly transforming numerous sectors during the so-called "Fourth Industrial Revolution" (Industry 4.0) (Zervoudi, 2020). The major digital tools and techniques employed in digital farming are given in Fig 1.

Smallholder farmers access to information, inputs and markets is already being improved by the proliferation of mobile technology, computing and remote sensing services. The phrase "Industry 4.0" first appeared in German, where it described quick changes in the financing, training and design, production and operation of manufacturing systems and goods (Fuchs, 2018).

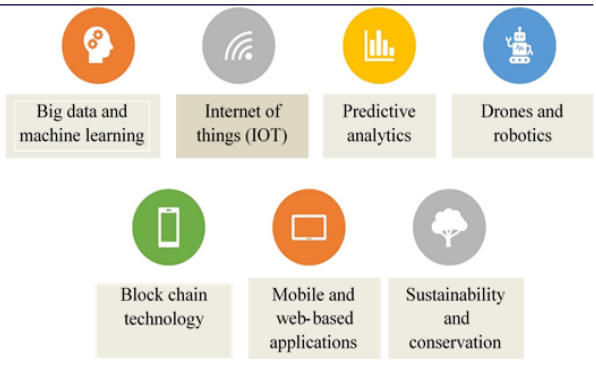

Fig 1: Various digital tools and techniques employed in digital farming

Key Components Of Digital Farming

Utilizing a range of cutting-edge technology, digital farming gathers, examines and applies data-driven insights to agricultural methods. ICT-based farming where the entire framework depends on certain sensors, software logic, connectivity and navigational assistance systems with geospatial systems utilizing drones and satellites is referred to as "digital farming." The newest technological advancement is drone technology with AI capabilities, which may be used for a variety of tasks like drip irrigation, pesticide treatment and crop and field monitoring. Recently, strong computer vision algorithms have been utilized to identify damaged crops, weeds and sick plants using drones. Here are the key components of digital farming,

IoT and sensor technology:

The Internet of Things and its sensors are essential to digital farming. They offer up-to-date information on every facet of the farming environment. By measuring pH, nutrient content and moisture levels, for instance, soil sensors help farmers optimize their fertilization and irrigation strategies (Rajak *et al.,* 2023). Farmers can better plan their activities by using weather stations with sensors, which can forecast weather patterns. Livestock sensors track the well-being and actions of animals, facilitating early disease identification and improved welfare management.

Drones And Satellite Imagery:

Due of their ability to provide high-resolution photographs and data from above, drones and satellites are essential tools for digital farming (Inoue, 2020). These photos are useful for tracking crop health, spotting pest infestations and evaluating the general state of the fields. Multispectral cameras on drones allow for the detailed collection of information about plant health that is not visible to the human eye. On the other side, a larger viewpoint is provided by satellite images, which enables extensive monitoring and analysis.

Big data analytics and AI:
Big data analytics and artificial intelligence (AI) algorithms are used to process the enormous volumes of data produced by sensors, drones, and satellites (PrakasaRao *et al.,* 2021). These technologies forecast future results, identify patterns and trends and suggest the best farming techniques. For example, AI-driven systems can forecast insect outbreaks based on past data and meteorological circumstances, or evaluate soil data to recommend the best crop kinds for a given area. As more data is processed by machine learning algorithms, their accuracy increases steadily, producing more accurate and trustworthy conclusions.

Farm Management Software:
Integrated farm management software, which gathers information from multiple sources and gives farmers a unified platform to manage their operations, is the foundation of digital farming (Abiri *et al.,* 2023). These software programs provide resources for organizing, observing and maximizing farming operations. They can help farmers organize their workflows and make data-driven decisions by scheduling chores, managing budgets, keeping track of inventories, and generating reports.

Digital Farming And Sustainable Development
There are two primary areas in which the sustainability of agriculture in the context of the economy's active digitization can be examined. The introduction of digital technology must be sustainable in order to have a long-term good impact and the process of the economy's digital transformation affects the sustainable development of agriculture and rural areas. Three key areas highlight how digitalization plays a significant role in accomplishing the objectives of sustainable development in agriculture. In order to improve sustainability in agriculture, incorporation of digital technology as well as the kinds and traits of sustainability indicators, internal and external factors, and instruments (Popovych, 2024). According to Lin and Li (2023) the digital revolution in agriculture in China is what's driving green growth in the sector. It contributes to green growth by greatly enhancing the invention of green technologies, agricultural scale operation and agricultural cultivation structure optimization. In addition, green agricultural progress was notably accelerated by the industrialization and digital agriculture infrastructure, while the quality of the digital agricultural subjects may have played a bigger influence. Thus, enhancing rural human capital and fortifying the digital infrastructure in rural areas support the growth of sustainable agriculture across the country. Digital agriculture, which uses geospatial and digital technology to monitor, evaluate, and manage genetic, climatic and soil resources, provides an example of how to address this challenge and strike a balance between the social, environmental and economic aspects of sustainable food production (Basso and Antle, 2020).

AS per observations of Mondejar *et al.* (2021) an equitable, ecologically sustainable, and healthy society can be ensured by proactively addressing difficulties related to the Sustainable Development Goals (SDGs) of the United Nations through the development of smart systems linked to the internet of things only. The advancement of information technologies is becoming more and more crucial to the technological and economic success of every nation in the current, rapidly changing era. Nearly every area of the economy has been impacted by the Fourth Industrial Revolution's development, which is centered on digital production. By putting the digital agenda into practice, the circumstances for improving the agro-industrial complex's efficiency and rural communities' sustainable development will be created. It includes using new business procedures, digital models and the creation of digital assets in addition to the use of information and communication technologies (Turchaeva and Golovach, 2021). In order to support the agroecological transition (AET), better understanding, mastery, preparation, equipping and support the deployment of digital technology in agriculture and the food chain, while taking into account the ways in which it will transform sectors and their ecosystems commendably (Maurel *et al.,* 2022).

Digital farming in India
India's agriculture industry has long been the backbone of the country's economy, employing a sizable fraction of the workforce and making a major GDP contribution. India leads the world in the production of wheat, paddy, pulses and wheat. One of the biggest agricultural research systems in the world is the National Agricultural Research System (NARS), which consists of State Agricultural Universities and the Indian Council of Agricultural Research (ICAR) institutes. In India, agriculture employs more than 42.86% of the labour force (as of 2022), generates 16% of GDP (gross domestic product) (2020-21), and ensures food security for around 1.3 billion people (Keelery, 2024; O'Neill, 2024). Thus, in this case, technology and the digitalization of agriculture act as a catalyst to enhance and raise productivity.

The implementation of digital technologies in agricultural activities is encouraged by the report on doubling farmers' income by 2022 in India, as it will contribute to an increase in farmers' income. Digital agriculture must replace traditional agriculture in order to realize the goals of the Sustainable Development Goals (SDGs) and the Self-Reliant India Movement. The Digital Agriculture Mission (2021-2025) and the Digital Agriculture Ecosystem consultation document from the Indian government are the first stages toward digitalizing Indian agriculture (GoI, 2021). As producers, farmers are the primary participants in the food production and supply system. Therefore, without guaranteeing the welfare and contentment of farmers, it will be difficult to attain and maintain food security. Singh *et al.* (2022) opined that the future of Indian agriculture rely heavily on digital agripreneurship. The fact that segregated small-holder farms are so common in India contributes significantly to the country's delayed adoption of digital farming since it makes data collection more challenging. The limited penetration of mechanized equipment and frequent natural disasters, including as floods, droughts and excessive monsoon rains, have also had a significant impact on the sector's use of digital solutions. A customized approach is therefore needed to implement digital agriculture on a typical Indian small farm which can then be scaled up and made available to many Indian farmers. The following measures are recommended to make digital agriculture a success across India,

Low cost technology:
Over $1,000 USD is the average yearly income for Indian farmers. The unstable financial conditions that the average Indian farmer faces are explained by this poor income (Sachdeva, 2024). So, cutting the price of technology will be beneficial.

Portable hardware: Plug and play hardware has a greater chance in the Indian market since most Indian farms are tiny. Additionally, agricultural land leasing is commonplace under a variety of farming agreements, so a farmer who is now farming on a particular piece of land may relocate to another farm plot for the upcoming growing season. In these kinds of situations, farmers would be better off investing in portable equipment.

Renting And Sharing Platforms For Agriculture Equipment And Machinery: Due to limited funding and small-scale farming, there is potential for digital platforms that provide equipment rental and sharing services rather than full purchases (Priya *et al.,* 2024). A few agritech startups already offer equipment rental services like the AgroEcom (Swarnamalya and Anbumani, 2023).

Academic support: Through numerous locally organized programs and government efforts, farmers are continuously engaged in interactions with local agricultural organizations and academic institutions. The availability of training facilities from academic institutions and agricultural organizations will increase farmers' adoption of digital technology even in rural India (Pawar, 2022).

India has implemented initiatives and policies that have digitally intervened in the agrarian industry. However, because majority of the projects are restricted to serving governance objectives and informing farmers, India falls behind other countries in the adoption of digital technology at the farm level. In the Report on Doubling Farmers Income by 2021, the use of cutting-edge digital technologies in agriculture was highlighted. However, greatest level of public participation is necessary for any government-led project to succeed.

Digital Agriculture Initiatives In India
India's agricultural environment is changing as a result of digital agriculture projects, which are making it more robust, sustainable, and efficient. These programs provide farmers with the resources and information they need to better their livelihoods, maximize their practices, and raise productivity. Digital technologies will become more and more important as they advance in assuring food security and encouraging sustainable development in India's agriculture industry. The major initiatives by the government in this line are,

The central government has introduced the Digital Agriculture Mission 2021-2025, in order to promote digital agriculture through pilot initiatives with Cisco, Ninjacart, Jio Platforms Limited, ITC Limited, and National Commodity and Derivatives Exchange (NCDEX) e-markets Limited (NeML) where five Memorandum of Understandings (MoUs) were inked. In order to promote and expedite projects utilizing cutting-edge technologies such as artificial intelligence (AI), blockchain, remote sensing, robots and drones, the Digital Agriculture Mission 2021-2025 was established.

India is home to more than 1,000 agri-tech start-ups and the industry has long been backed by a number of investors, loan funds and venture capital firms. These startups help farmers improve farming practices and yield with their creative ideas.

In order to give farmers access to up-to-date information and guidance, NITI Aayog and IBM have collaborated to develop an AI-powered crop production forecast model. It helps improve crop yield, soil quality, management of agricultural inputs and early disease breakout alertness.

To enhance farming and knowledge sharing, Cisco developed an Agricultural Digital Infrastructure (ADI) solution in August 2019. This was crucial to the development of the Department of Agriculture's National Agri Stack data pool.

In order to empower farmers, the Jio Agri (Jio Krishi) platform was launched in February 2020 and digitalized the agricultural ecosystem throughout the whole value chain. The main purpose of the platform is to provide advice by using data from independent applications. Its sophisticated features combine data from multiple sources, feed it into AI systems, and then provide tailored, accurate suggestions.

Climate-smart farming techniques are being adopted by India step by step, helping to reduce greenhouse gas emissions from agricultural activities and change the nation's environment. For example, farmers in the village of Dhundi in Gujarat have started using solar power and other renewable energy sources for irrigation.

In order to assist India's small-holder farmers, Microsoft and the Indian government have partnered to launch the "Unified Farmer Services Interface" pilot initiative where this collaboration wants to raise agricultural productivity using AI sensors and manage prices better to increase farmers' incomes. The partnership would hasten the application of AI in agriculture.

The government's Sensor-based Smart Agriculture (SENSAGRI) initiative consists of six institutes. In this design, drones would be used to survey over land tracts effectively, gather invaluable information, and provide the data to farmers promptly.

Launched by the Ministry of Agriculture and Farmers' Welfare, eNAM is a pan-India electronic trading portal that connects existing Agricultural Produce Market Committees (APMCs) to create a unified national market for agricultural commodities.

CONCLUSION

An important development in the pursuit of sustainable agricultural growth is digital farming. Farmers can increase productivity, improve resource management and have a minimal environmental effect by utilizing the capabilities of IoT, AI, big data analytics, drones and other technology. Beyond individual farms, digital farming has advantages that support economic expansion, environmental sustainability and global food security. However, overcoming obstacles pertaining to initial investment, data privacy, technical know-how, interoperability and environmental effect is necessary to fully realize the potential of digital farming. Digital farming presents a viable route forward as global pressures on food supply and natural resources increase. In the rapidly changing field of agriculture, digital farming is a shining example of innovation that points the way towards a more productive, efficient and sustainable future. Examining the fundamental elements, advantages and difficulties of digital farming reveals that this strategy is not merely a fad but rather a need in a globalized world with expanding food needs and environmental concerns. With digital farming, farmers can decrease resource waste, make data-driven decisions and improve food security worldwide. It enables the farming community to cultivate land while protecting biodiversity and nature. To move forward, addressing these challenges and ensuring that digital farming is accessible to all farmers will be paramount. Digital farming is not a one-size-fits-all solution, but rather a toolkit of innovations that farmers can tailor to their specific needs. It represents the future of agriculture-one where data, technology and tradition come together to nourish a growing world population while safeguarding the planet. To sum up, digital farming is not simply a transformation of agriculture; it's a transformation of our relationship with the land, the environment and the food farmers' produce. Thus it's a journey towards a more sustainable, efficient and resilient future for farming and our planet.

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