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Digital Agriculture: The Future of Indian Agriculture

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Review Article

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ABSTRACT

Agriculture continues to be the dominant economic sector in India in terms of providing a living. Of the population, 58.2% are employed by it. The success of the agriculture sector determines the nation's social change and economic expansion. Although the amount produced by agriculture per person has been steadily increasing recently, the sector's GDP contribution has been declining.

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The main issue facing the so-called agrarian Indian economy is the slowdown in agricultural growth. Numerous factors contribute to the slowdown, including inadequate public funding for R&D and irrigation, ineffective input delivery, fragmented land, antiquated tenancy laws, a lack of contemporary market and rural infrastructure, unsuitable input pricing policies, and so on. Agriculture has embraced technology as a solution to all of these issues. Information and communication technology (ICT) and agriculture are coming together to create a new growth engine that makes all production, distribution, and consuming processes more efficient. The evolution of Indian agriculture and the concept of digital technology are the main topics of this paper.

Keywords: Digital; ICT; agriculture; technology; artificial intelligence; big data analytics; IoT.

1. INTRODUCTION

Over 58% of rural households in India rely on agriculture as their primary source of income, demonstrating the country's high reliance on this industry. In FY20 (PE), the combined gross value added (GVA) of agriculture, forestry, and fishery was projected to be Rs 19.48 lakh crore (US$ 276.37 billion) [1]. The contribution of agricultural and related sectors (such as forestry, fisheries, cattle, and agriculture) to GDP during the 2018–19 fiscal year, at 2011–12 prices, is projected to be 16%. Despite the fact that industry and service-based sectors are growing at a faster rate than agriculture in the Indian economy, agriculture is still important given the country's population growth rate [1]. It is increasingly likely that as more and more people move to large cities, the trends in food and consumption patterns that have been observed in India would alter. Additionally, agriculture as a sector is likely to undergo digital transformation to keep up with the pace of its customers as the rest of the nation moves towards digital means.

In the agricultural sectors of the United States, Australia, and Israel, digital technologies such as artificial intelligence, the Internet of Things, big data analytics, satellite imagery and remote sensing, machine learning, unmanned aerial vehicles (drones), and robotics are finding extensive uses. With shifting consumer needs and behaviours, India is also making room for these technologies, though it is still in the very early stages of this transition. In India, the average farm size is 1.08 hectares, and 80 percent of farmers are in the small and marginal group, meaning they have access to modest land holdings. As a result, Indian farmers have less need for more sophisticated technology such as drones and farm robots. The majority of information exchange and capacity building technologies are provided to India's farmer population through mobile applications and other mobile-based services, according to current trends in the country. These technologies are far more appropriate given the majority of Indian farmers' financial and literacy backgrounds, as they are less costly and technologically sophisticated.

While not exactly like other nations, this trend in technology usage shows encouraging progress in India's digital agriculture transition. This is supported by a 2014 World Bank report titled "What's Cooking: Digital Transformation of the Agri-Food System," which found that 190,00 data points were produced daily on average per farm. Additionally, researchers project that by 2050, each farm would generate 4.1 million data points daily. When examined and shared as knowledge, so many data points can be very helpful to farmers in terms of productivity and identifying target markets for their food. The Indian governments recently enacted farm regulations, as they are colloquially called, seem to be an attempt to draw in additional funding and investments for the future development of Indian agriculture. Given the amount of agricultural products used in India, digitization won't happen any faster if privatisation is incorporated into the farming sector. Additionally, initiatives like contract farming are in line with the shifting needs of contemporary consumers for food, leading to interconnected agriculture value chains. In these chains, not only farmers but also processors, input suppliers, traders, and consumers are empowered by digital technology and engage in information-related and other potential transactions with one another in order to deliver what the market actually demands [2].

2. THE INDIAN AGRICULTURE SECTOR FACES SIGNIFICANT OBSTACLES

The issues facing the agriculture industry would have a significant impact on both the general development of India and the wellbeing of its

rural impoverished. The following are the challenges:

- With 2 billion more people on the planet by 2050, India would need to feed 750 million of them.
- India's current resource consumption is 50% quicker than the global average.
- As a result of soil erosion and urbanisation, India loses farmland the size of a football pitch per second.
- Of India's entire land area of 329 million hectares, about 37% (120.40 million hectares) of its total geographical area is impacted by various forms of land degradation.
- Each hectare of fertile soil loses 16.4 tonnes on average each year.
- Although only holding 33% of the nation's cultivated land, India's small-holder farmers—those with fewer than 2.0 hectares of land—account for 78% of the country's farmers and produce 41% of its food grains.
- Most farmers cannot afford the exorbitant expenditures of the current farming technology.

Although food scarcity may seem like a distant issue at this point, India may have to deal with it in as little as 15 years. With just 15 million jobs created in the last ten years, India's growth has been primarily jobless. The likelihood of a recovery appears slim given the sharp decline in employment per factory over time.

Therefore, in order to grow this industry and make the agricultural sector far more productive, globally competitive, and diverse, policy makers must start and incorporate policy actions and public programmes.

3. A VALUE-CHAIN ANALYSIS OF AGRICULTURE

In their paper, [3] outlined the crucial elements of designing an agricultural value chain, emphasising that the first step in the process is to analyse the value-creating activities of the production and distribution process, which will eventually give the final products the qualities that consumers will find appealing. Considerations including product flow, cash flow, information flow, performance-based incentive programmes, and governance systems come next. [4] emphasised the value of knowledge transfer and the need for it to be appropriately modelled to meet the unique needs of farmers in order to expand on their already acquired body of knowledge.

To foster trust and boost farmers' dependency on these technology models, information must also be disseminated in a clear, concise manner that takes into account all linguistic, cultural, and other relevant hurdles provided by Indian farmers. Apart from that, the appropriate timing of information transfer based on the specific piece of information, such as during production or the emergence of financial needs, and the accuracy of the information along with the appropriate procedures and guidelines for putting it into practise are very important. Four essential components of an agriculture value chain are production, accumulation, post-harvest processing, and delivery or distribution, as noted by [5] in his report. Input delivery, financial access, and service delivery are the three main economic activities he used to categorise the value chain.

In their study, [6] emphasised that there is a widespread deficiency in appropriate coordination across the many components of the agriculture subsystems. Closing that gap will increase profitability and structure for every link in the agriculture value chain. The various areas of the agriculture value chain where digital technologies are finding significant applications were highlighted in [6]. These areas include training and empowerment, traceability, market access, financial access, environment sustainability, extension activities, expert advisory services, and government and policy-based regulation activities. Farmers and other participants in the agriculture value chain have shifted to digital value-chain finance, according to [7]. These financial services flow towards or enter from any point of the value chain to give members the financial options—such as insurance, working capital, or investment financing—necessary to enhance the growth of those participating in the said value-chain. Going digital has increased market prospects and enhanced the efficiency of financial aid transactions by removing potential impediments.

In their study, [8] emphasised the findings of several researchers regarding how ICTs facilitate information access, capacity building, market access, credit, and interconnectivity among various value-chain participants. [9] noted in their analysis that the majority of agribusiness startups

Fig. 1. Overview of digital agriculture

provide IoT, big data, and artificial intelligence (AI) based solutions along the value chain. According to [10], a constant flow of information via digital tools keeps all the participants in the agriculture value-chain informed about the various practises being used and the likely actions that might be taken based on the data-driven predictions thereof. These may have to do with target markets, farming management, herd management, likely pricing points, transportation operations, etc.

Trivedi et al. [11] emphasised that every value chain might experience a fundamental shift in its dynamic structure at any time due to the introduction of new technical choices. In light of this, the agriculture value chain for agribusinesses was split into three segments: before-the-farm, inside-the-farm, and after-the-farm. The majority of agri-techs (about 77%) were discovered to be addressing problems that arose within the farm out of these three distinct categories. Just 9% of agri-techs were concentrated on activities that took place before the farm, while 14% were focused on solutions that would occur after the farm. Nagesh et al. [12] emphasised how ICTs not only provide farmers with knowledge that empowers them, but also raises their degree of engagement and interaction with other members of the value chain. Additionally, there is less risk associated with weather, prices, markets, and even technology. Chandra et al. [13] underlined the pressing need to create stronger tech-enabled agriculture value-chains in order to support transformative agricultural technologies and to give smallholder farmers particular advantages.

Denis et al. [14] noted that large amounts of data being generated on farmer fields can be used to create a digital twin of physical supply chains, wherein data analytics can be used to manage various activities such as production, storage, warehousing, transportation, and marketing. Users can also receive customised mathematical algorithms to help them with tasks like inventory optimisation, food patterns, profit maximisation, and markets to target. The supply chain technology and output market linkage segments are receiving the majority of investments in the Indian agri-tech sector, according to a report by [2]. Investor interest is also being piqued by financial services, quality management, and traceability. In their research, [15] emphasised that, given the circumstances surrounding the coronavirus pandemic, digitising agriculture value chains has become imperative in order to facilitate communication among the various

stakeholders involved. This entails putting consumers and growers in direct contact by enabling services like digital payments to develop a more dependable and forward-thinking agricultural sector.

4. AGRICULTURE'S DIGITIZATION

In India, a recent trend aims to boost productivity in all production, distribution, and consumption processes by combining information and communication technology (ICT) with agriculture. Another way to define this system is as an integrated agricultural system. The primary components of the integrated agricultural system are digital control equipment and data processing for network automation, digitalization, transmission, and collection of agricultural activities (Tang, 2002). Today's agriculture and technologies including information technology (IT), biotechnology (BT), environment technology (ET), and nanotechnology (NT) have come together. Wang (2002) Additionally, its primary focus is on topics like high-quality, organic production, labour strain reduction, and facility quality control. Second, developing a system that provides food safety information is crucial to meeting consumer needs at the manufacturing and distribution stages. Thus, the agriculture farming automation system needs to enhance its use of IT applications. In addition, sophisticated IT-based distribution technologies, such as distribution data convergence, must be implemented at the distribution and processing phases. These are the minuscule segments of the digital farm system that contribute to the larger database that comprises the entire agriculture system.

5. SIGNIFICANCE OF DIGITAL TRANSFORMATION

Farmers will benefit from a digital transformation in a number of ways.

Access to Finance: As a result of the several issues previously mentioned, Indian farmers currently suffer from a severe lack of funds. Because of the visibility and knowledge that comes with being digital, farmers that are undergoing digital transformation are able to acquire money from a variety of sources.

Climate Change Forecasts: In India, it has proven to be challenging to predict changes in the weather and how they would affect agriculture, especially when compared to other developed nations. Knowing what information is available about anticipated climate change will enable farmers to choose the best seed to plant in order to meet market demand.

New Technology and Farm Equipment Accessibility: In many wealthy nations, farming is increasingly reliant on robotics. India has not yet experienced this development; hence this shift is imperative.

Contributions for Improved Soil Fertility and Soil Structure: Indian farmers hardly ever research the soil's fertility and, consequently, the type of seed that should be planted. The Indian farmer of today develops what has been done in previous generations. Thus, a more scientific approach to agriculture is required.

Access to Markets: Despite putting in a lot of effort today, the farmer does not receive a just reward for his labour. The farmer receives a small payment in comparison to the middlemen's earnings because of the middlemen who are involved in the purchasing and selling of the farmer's goods. Therefore, a platform that will allow farmers to sell directly to consumers rather than through middlemen is required.

Information Access: Today's farmer bases his produce on what his colleagues plant and what has historically been cultivated in the area. It's not always the case that what worked yesterday or for someone else will work today or for us. In order to increase production and secure the necessary funding, the farmer will need to test out new experiments based on the information at hand. It is anticipated that the digital transition would address issue suitably.

Small land holdings: Given the quantity of uncultivated land, it is a truth that many farmers nowadays have very little land, which makes it difficult for them to raise the proper crops. If we are to overcome the obstacles, this must alter.

Predictive analytics: If the agriculture industry is engulfed in this digital transformation, the amount of data that will be available will assist the farmer in growing the correct crops at the right time. This is done by utilising the newest technology available on the market. As a result, the Indian farmer's standard of living would increase, which would inspire more people to take up farming.

Thus, by employing digital transformation, the farmer can benefit from the aforementioned inputs.

6. BUILDING CAPACITY AND EXCHANGING INFORMATION

The food business is driven by a number of complex processes involving aware consumers, which puts the one with knowledge and understanding of the same in front. This is why, unlike in the past, [3] described in their article the role of knowledge and information in agriculture is increasing. Furthermore, as agriculture becomes more skill-based and more research is focused on using technologies like precision agriculture to increase productivity, the amount of risk can only be managed by having the best possible knowledge and understanding of the dos and don'ts in order to guarantee the necessary returns on such significant levels of investment. This suggests that individuals with the appropriate information will inevitably be more effective and safe in this field.

Moreover, private sector organisations have a strong hand in determining who has access to such information and whether to deny it to competitors in order to control competition, since information is turning into a major source of competitive advantage in this new era of agriculture where the public sector no longer controls its dissemination.

Similar to this, [16-19] emphasised in their report the benefits of crisis organisation information services, financial inclusion, mobile phone access, and timely information among other things in creating more integrated and sustainable agriculture value chains. Yared et al. [20] came to the conclusion that, in the field of agricultural knowledge and advisory services, digitization is expected to bring about a number of significant changes in trends, including improved connectivity between various actors in the agricultural value chain with emerging technological solutions, a diversification of transparency in the information exchanged among these actors, the need to sort the priorities held by various stakeholders as digitization.

According to Trivedi et al. [21] the digital transformation of agriculture plays a crucial role in the timely distribution of information, the development of customised products based on customer needs, traceability, the appropriate implementation of policies, and the creation of an overall connected value chain in agriculture that promotes sustainable and environmentally friendly practises.

7. ACCESS TO SMARTPHONES AND MOBILE PHONES FOR FARMERS

Uphoff et al. [19] pointed out in his study that farmers have had access to the internet for the past three to five years, which has improved connection between various players in the agriculture value chain. This has made it possible for farmers to gain from ICTs in a variety of ways, including informational and market access, mobile banking, and weather-related intelligence. Additionally, more farmers are using smartphones and cell phones, which makes it easier for them to access the aforementioned services without having to pay for expensive desktops, laptops, or other hefty hardware components. In addition, social media platforms like Facebook and You Tube offer low-cost and simple ways to exchange knowledge through photographs and other media, facilitating greater communication between farmers and other groups like researchers, politicians, and specialists. The significance of mobile financial services—one of the most promising areas for agriculture-based mobile applications—was underlined by [16] in his paper. Here, governments can connect with farmers, particularly those from low-income backgrounds, and provide them with a variety of credit options to help them improve their standard of living.

In their work, [17] emphasised how mobile phones have made it possible for farmers to reduce their trip expenses and receive timely market information, which is extremely advantageous, particularly for perishable crops. Additionally, farmers who are not tech-savvy can understand the features of mobile applications designed for them, such as easily recognisable iconography. In addition, mobile applications offer a wealth of capabilities like text, images, music, video, and animations, making them a very dynamic way for farmers to stay informed about new advancements in the market and in the agricultural sector.

7.1 Mobile Apps Focused on Agriculture

In their report, [22] detailed the various domains in which mobile applications are utilised in the agricultural industry. These domains include market intelligence, trading platforms, operational tracking and monitoring, quality assurance, logistics management, financial services, and data gathering and surveillance. The difficulties in creating mobile applications for agriculture in underdeveloped nations were brought to light by

[23]. These difficulties stem from low levels of digital literacy and insufficient exposure to software-based services, which make it difficult to design and construct an appropriate user interface.

Many applications are not able to target small and marginal farmers with tiny land holdings because they are created with large farmers in mind. Applications for rural farmers should be designed with very intuitive platforms that don't rely just on text-based interactions. In their study, [24] described how mobile applications enable the dynamic broadcast of information with real-time data about the market, weather, seeds, and fertilizers—something that is typically not achievable through SMS services. This is due to the fact that these services only facilitate one-sided dialogue, which is insufficient for the dynamic circumstances that farming communities face, which call for problem-solving that is done back and forth.

In her study, [25] showed how the majority of mobile applications pertaining to agriculture that are offered for free on the Indian market are free of charge. Additionally, the majority of mobile apps may be found on the Google Play store, which comes pre-installed on the majority of Android-powered handsets. This demonstrates the current trend in the digital agricultural business, which is to encourage farmers to embrace digital connectivity by using the least expensive and most straightforward channels. To delve deeper into this subject, [26] noted in their paper that mobile applications that can tailor their services to a particular field's requirements and geographic location, as well as provide information on a variety of topics ranging from customer preferences to production practises, are more likely to find applications among the greatest number of farmers. [27] noted that the most popular features added to mobile applications these days are GPS and camera capabilities.

Kumar et al. [28] highlighted the potential of mobile applications to connect distribution networks in the agriculture value-chain, involving producers, suppliers, and buyers. This can increase transparency and efficiency and lessen the need for middlemen while also lowering the likelihood of succumbing to various scams and administrative pressures. In their work, [29] noted that, as of 2016, the greatest number of mobile applications in the Indian agriculture industry were centred around the farm management area of specification.

Diseases and pests, market intelligence, agricultural information, skill development, and conference applications were some of the other fields of mobile app development. They also made the point that, despite a number of obstacles to their use, such as their multilingual interfaces and difficulty of use, mobile applications are still a very dependable way for farmers to connect with the market and get real-time information to improve their farming practises. In their paper, [30] outlined the various mobile applications being developed to enable farm-to-fork connectivity in the agriculture value chain. This would enable farmers to connect with potential customers to meet their needs and address issues of middlemen, waste, and competitive prices all at once.

According to [31] smart agriculture would have a global market value of around 23.14 billion US dollars by 2022. He also discussed the advantages of mobile applications for farmers, such as easy-to-use guides that function as information distributors at reasonable costs, quick access to field data collected by sensors installed for things like pest infestation warnings, nutrient dose recommendations, and access to GIS (Geographical Information System) services for the purpose of collecting soil data for improved productivity and management. Information sharing and peer connectivity, online lending services, e-marketplaces, weather forecasting, GPS tracking, traceability of value-chain processes, and livestock management services are among the various mobile applications in the agriculture sector covered in this article. These programmes offer a variety of functions, such as chat rooms, payment gateways, machine learning, cloud support, information stacks, and weather forecasts [32,33].

7.2 Infrastructure's Role in Agriculture's Digital Transformation

Trivedi et al. [34] emphasised the significance of digital infrastructure for facilitating the establishment of a digital economy. They emphasised how government agencies should encourage greater investments in the development of digital infrastructure, such as broadband, to enable more people to access the internet and at a lower cost. According to [35], Bangalore is home to three out of every four IT-based enterprises. This is because the city has a supportive government infrastructure and progressive policy framework. Also, Bangalore,

Karnataka, is home to one in every four Indian digital start-ups. Mumbai, India's financial hub, is the location of numerous emerging fintech enterprises.

Despite this, the cost of living in Mumbai and Delhi is higher than in Bangalore, which makes the atmosphere less conducive to startups. Delhi lags behind the two cities mentioned above for other significant reasons, including safety and lack of acceptance. When it comes to the startup culture, Chennai is also regarded as a centre. In addition, growing start-ups are beginning to acknowledge Pune, Hyderabad, Ahmadabad, and Kolkata as home to Tier-1 and Tier-2 cities.

Ohlan et al. [36] reported in her study that Bengaluru-based agri-tech firms raised the highest amount of financing in 2016. Delhi and Mumbai came in second and third, respectively. This emphasises the significance of infrastructure connectivity, whether it be in the form of internet connectivity, roads, or energy, in generating chances to grow the digital agricultural industry in India. She also mentioned that, of the start-ups established in the previous five years, 50% were initiated in 2015 and 2016.

7.3 Obtaining a Patent for Digital Technologies is Difficult

In their article, [37] emphasised the shortcomings of the Indian Patent Act, which makes it clear that a computer programme cannot be patentable on its own unless it includes hardware components that are necessary for the programme to function properly and produce outcomes that go beyond information generation. Additionally, they made note of the fact that the guidelines do not clearly describe or define the specific types of software inventions that end up being patented, necessitating adequate handling, particularly in the case of MSMEs and entrepreneurs. According to [38], software in India can be patented if it is linked to an invention—that is, if the innovation includes hardware that is just as important as the computer programme.

Williams et al. [39] argued that when considering whether to patent mobile applications, one should first evaluate the longevity and sustainability of the business, given that the majority of apps expire within six months, while patents require at least a year to obtain. Additionally, in order for the IPO to view a software patent favourably, extra care must be taken while explaining the invention in question and ensuring that it satisfies all legal and technical requirements in the patent application. Additionally, developers can choose to have their software codes protected by copyright since software programmes by themselves are not patentable in India under the terms of the patent laws.

7.4 Digital Goods as Opposed to Digital Services

The present change in the digital economy, wherein digital services are chosen above digital products for development, was brought to light by [39]. In their work, [40] emphasised that digital services are built on an individual approach, wherein the demands of specific consumers are prioritised and evaluations and feedback are taken into account to improve delivery in the future. Additionally, in this case, clients get from personalised services, while service providers gain from devoted clients. [41] outlined the benefits and drawbacks of providing digital goods and services. She made the point that although developing digital products is simple and inexpensive, their primary purpose is to cater to a large audience rather than providing a customised experience for each individual user. As opposed to this, digital services give developers the ability to design far more customised deliverables, giving them command over their customers' experiences and the ability to tailor their products to meet their unique demands.

7.5 Uses of Digital Technology

In their paper, [42] described how investing in bulky hardware components and antiquated techniques is reduced when using a decentralised data storage system. Through devices with cloud accessibility, farmers can access various types of data linked to weather, soil, and other related fields throughout the day for reasons such as farm management. In addition to farmers, other system participants such as specialists, consultants, and researchers can also access this data without physically visiting the farmers, which saves a significant amount of time and money. These kinds of systems also allow for the healthy exchange of services and the unrestricted flow of information, which promotes the general growth of Indian agriculture. In his paper, [43] illustrated how IaaS, PaaS, and SaaS can be used in the agriculture industry. High-tech farming

infrastructure is one example of an IaaS application. Drones, satellites, robots, and sensors are examples of PaaS technology. Big data analytics, artificial intelligence, information, and monitoring software are examples of SaaS applications. This article also outlines four methods for digitising a farm: installing sensors, linking the sensors to a cloud platform or hardware item, utilising cloud applications to leverage big data analytics, artificial intelligence, and other analytical services to transform field data into actionable insights, and enabling farm equipment to convert feedback and recommendations into actual farm operations.

Elijah et al. [44] emphasised the use of wireless sensors for the implementation of Internet of Things (IoT) and data analytics-based techniques in order to boost agricultural productivity and efficiency and introduce smart agriculture. IoT applications use several technologies, such as radio frequency identification, cloud computing, and others, in addition to wireless sensors. [45] outlined the various uses of information technology in agriculture, including the sharing of information about production methods, market intelligence, post-harvest procedures, consumer preferences, weather forecasting, input and credit availability, early warning systems for diseases and pests, and the use of web-based platforms to organise farmer education and training sessions.

Trendov et al. [46] emphasised the growing number of AI applications in the cattle industry for disease prevention and animal identification. Three different types of cloud computing models were clearly illustrated by [47] in their paper. These models included data banks, tablets, computers, and mobile phones for infrastructure-as-a-service, operating systems for platform-as-a-service, and web applications and other software for software-as-a-service cloud platforms. Additionally, a number of cloud computing applications in the agriculture industry are described, including quality monitoring, real-time crop monitoring, weather information databases, pest and disease databases, information sharing databases, and databases connected to new technologies and developments.

The primary domains of IoT use in agricultural, according to [48] article, are monitoring, controlling, and tracking solutions; of these, 71% of studies have focused on monitoring, 25% on controlling, and 5% on tracking applications. These application fields can also be further classified into specialisations including precision farming, soil monitoring, temperature monitoring, disease monitoring, fertilisation monitoring, and irrigation monitoring and management.

The most studies in this field of study are focused on precision farming and irrigation monitoring and control applications. The growing number of uses of the Internet of Things in the agriculture sector for tasks such supply chain management, crop monitoring, irrigation, farm management, and disease monitoring was demonstrated by [49].

Pawar et al. [50] outlined the various uses of cloud computing in agriculture, including crop data, crop monitoring, soil data, farming data particular to an area, and agricultural marketing. Cloud computing can be categorised into three types: infrastructure as a service (important for network architects), platform as a service (useful for application developers), and software as a service (designed for end users, particularly farmers). [51] described the various applications of artificial intelligence in the agricultural sector. Among the applications covered in this study are chatbots, image recognition and perception, robotics, autonomous systems, vision-based weed detection technology, weed prevention robots, automatic plant irrigators, soil moisture sensors, drone technology applications for pesticide spraying, crop monitoring, yield mapping, yield calculation, and similar applications.

Based on the progress already made in the field of agricultural economics, [52] emphasised in their study a clear distinction between two categories of digital technologies, namely embodied and disembodied innovations. This classification allows digital technologies used in agriculture to be separated into two primary categories: first, software tools delivered in disembodied forms such as online platforms, farm management software, and mobile advisory applications; and second, precision farming technologies for both crop and livestock applications embodied as physical devices like sensors and machines.

7.6 Initiatives for Digital Agriculture in India

- The Union Minister of Agriculture and Farmers Welfare, Narendra Singh Tomar, introduced the Digital Agriculture Mission

2021–2025 in September 2021. 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), five Memorandum of Understandings (MoUs) were inked. In order to promote and expedite initiatives utilising cutting-edge technology like 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 angel investors, loan funds, and venture capital firms. These startups help farmers improve farming practises 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.
- A pilot operation named 'Unified Farmer Services Interface' is being conducted by Microsoft and the Indian government to provide support to small-holder farmers in India. The 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.
- Additionally, India is assisting farmers by offering agricultural loans that will boost organic farming methods and drastically modernise agriculture, with a focus on agri-waste management. In addition, the Pradhan Mantri (PM) Kisan Samman Nidhi programme has given $26.4 billion to 11 crore farmers. Furthermore, the market for organic goods has increased to $1.50 billion. In addition, the government is supporting agri-tech companies financially and pushing AI to transform farming and agriculture practises.
- India is always striving to create and execute laws that will increase the agriculture sector's sustainability. Given India's dynamic corporate structure, corporate-government partnerships can facilitate the development of a smart agriculture industry.
- The Indian government is launching various projects and activities in order to achieve objectives such as double farmer incomes and sustainable growth. As a result, a multi-stakeholder approach will be necessary for the widespread adoption of digital agriculture in India, with the government playing a key role as an ecosystem enabler.

8. APPLICATIONS OF DIGITAL TECHNOLOGY: OPPORTUNITIES AND CHALLENGES

Blommestein et al. [53] emphasised the various ways that ICT can influence farmers' futures. In order to transform farming into a cutting-edge industry with secure livelihoods, they include offering targeted training, setting up an effective communication channel for information sharing, and aiding in the general reduction of risk factors by integrating ICTs into routine areas like policy execution. [54] came to the conclusion that in the future, there will be an increase in the number of

research collaborations between public entities, CGIAR Institutes, foundations, and private enterprises. This will result in frequent technological development, which will in turn lead to a rise in private sector investments supporting the expansion of agriculture.

The difficulties in creating mobile applications for agriculture in underdeveloped nations were brought to light by [23]. These difficulties stem from low levels of digital literacy and insufficient exposure to software-based services, which make it difficult to design and construct an appropriate user interface. Many applications are not able to target small and marginal farmers with tiny land holdings because they are created with large farmers in mind. Applications for rural farmers should be designed with very intuitive platforms that don't rely just on text-based interactions.

Nagesh et al. [12] emphasised how one of the obstacles that prevent farmers from diverse regions from embracing ICTs for agricultural purposes is language. According to [55], FPOs are crucial in creating jobs and value for the underprivileged while also giving small and marginal farmers access to facilities that are comparable to those used by MSME employees. [56] came to the conclusion that, in order to realise the full potential of digital technology solutions, digital technologies must be enhanced from the farm and advisor level to new technology suppliers. Other than that, the key to fostering some genuine changes in the lives of persons for whom these technologies are being developed is to mix learning with collaborative techniques.

Despite having the second-largest area of fertile land in the world, [2] pointed out in their research that, when compared to the status of agriculture in nations like Israel, we are still far behind in terms of the use of more modern digital technology. According to [57] research, artificial intelligence will permeate every aspect of the Indian agriculture value chain by 2030. This will be achieved through the use of intelligent tools and self-mechanized equipment that will power labour-intensive operations as well as service-based ones, both on and off the field.

The research by [51] identified two primary obstacles that the Indian agriculture sector is facing, taking into account the country's economic circumstances and farmers' technical expertise. First and foremost, the technologies under development must become more resilient in order to withstand the unpredictable nature of farming and make judgements in real time to satisfy the fluctuating needs of an agricultural field. Second, the solutions must be more accessible and economical for the typical farmer to implement in his daily operations. The work by [58] addressed the main obstacles that digital progress in agriculture will have to overcome in the future. A few of these difficulties include a lack of funding, a smaller market that makes it difficult for companies to satisfy their development expenditures, expensive development costs for embodied technologies, and unfavourable business environments.

Birner et al. [59] identified two key elements—privatization and the emergence of Farmer Producer Organizations—that have enabled digital transformation of agriculture in India. In addition, he asserted that the majority of Indian technologies are still produced using models from outside the country, rendering them impractical for Indian farmers. The author also emphasises the value of pay-per-use technology and rental models, emphasising how these frameworks might enable Indian farmers—who are primarily impoverished—to obtain digital technologies on their own terms. His paper also highlights the role that FPOs play in providing small and marginal farmers with both financial and technological help [60-65] outlined the main obstacles that the digital advancement of agriculture has been encountering. The obstacles include inadequate power and electricity systems, telecommunication networks, inadequate policies and protocols to be governed by government agencies, a lack of digital literacy and skills among farmer populations, gender biases, particularly with regard to women's ownership and use of mobile phones, and other cultural reluctance to adopt digital technology [66-71].

9. CONCLUSION

When taken as a whole, these studies have shed light on a number of significant trends that have emerged in the process of digitising Indian agriculture, including the dominance of technologies based on information and capacity building, the growing use of mobile applications by farmers, the preference for digital services over digital products, the significance of infrastructure development, the status of patent applications and grants among Indian developers of digital technology. Given the current size and

significance of digital agriculture in India, further research is necessary to better understand the direction the Indian agriculture sector will take going forward and how to make this transition easier and more effective for all parties involved. Thus, it can be said that the technology platform will result in the agricultural sector's intended results, which include lower costs, more quality and production, higher pricing, lower risks, and eventually a sustainable ecosystem. To support this digital transition, numerous software companies including Microsoft have relationships with different State Governments in India. A few states that have made significant development in this area are Karnataka, Hyderabad, and Assam. In order to overcome the aforementioned obstacles and promote greater efficiency in the production, distribution, and consumption of agricultural products, policies must change to reflect the rapidly evolving digital landscape.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Biswas MRS. Will digital technology transform Indian agriculture? Research in digital revolution and new India? 2020;151-157.
2. Madan A, Putrevu R, Khurana S, Goenka S, Sinha D, Mor H. Agri-tech - towards. EY India; 2020.
3. Boehlje M, Hofing S, Schroeder R. Value chains in the agricultural industries; 1999.
4. Kumar S, JA. Information and communication technologies (ICTs) and farmers' decision-making across the agricultural supply chain. International Journal of Information Management. 2011;31.
5. Neven D. Developing sustainable food value chains. Rome. Food and Agriculture Organization of the United Nations; 2014.
6. Kumar S, Sharma A. Agricultural value chains in India: Prospects and challenges. CUTS International; 2016.
7. Mattern M, Ramirez R. Digitizing value chain finance for smallholder farmers. CGAP; 2017.
8. Saidu A, Clarkson AM, Adamu SH, Mohammed M, Jibo I. Application of ICT in agriculture: Opportunities and challenges in developing countries. International Journal of Computer Science and Mathematical Theory 2017;3(1).
9. Shukla GN, Jha A. Agri start-ups: Innovation for boosting the future of Agriculture in India; 2018. Nearly 70 percent of Indian farms are very small, census shows; 2015.
10. Jouanjean MA. Digital opportunities for trade in the agriculture and food sectors. OECD Food, Agriculture and Fisheries Papers 122, OECD Publishing, Paris; 2019.
11. Trivedi A. Reckoning of impact of climate change using rrl awbm toolkit. Trends in Biosciences. 2019;12(20):1336-1337.
12. Nagesh N. Impact of ICTs on Agriculture growth and development case studies from karnataka region. Raichur, Karnataka: National Institute of Agricultural Extension Management (MANAGE); 2019.
13. Chandra R, Been T, Bramley R, Godbole S, Kempenaar C, Mal Retal. Advanced technologies reshaping indian agriculture. Confederation of Indian Industry 125 Years: 189-2020; Food and Agriculture Centre of Excellence; 2020.
14. Denis N, Dilda V, Kalouche R, Sabah R. Agriculture supply-chain optimization and value creation. Retrieved from Mckinsey & Company; 2020.
15. Ravi Kumar KN, Babu SC. Value chain management under COVID-19: Responses and lessons from grape production in India. J Soc. Econ. Dev; 2021.
16. Miller C, Saroja VN, Linder C. ICT uses for inclusive agricultural value chains. Rome: Well-connected Agriculture value-chains; 2013.
17. Fielke S, Taylor B, Jakku E. Digitalisation of agricultural knowledge and advice networks: A state-of-the-art review. Agricultural Systems. 2020;180.
18. Hrustek L. Sustainability driven by agriculture through digital transformation. Sustainability;2020.
19. Uphoff N. Empowerment of farmers through ICT. Cornell University; 2012.
20. Yared M. ICTs in linking farmers to markets: Innovative Mobile applications and lessons learned from the past and the future; 2015.
21. Trivedi A, Awasthi MK. A review on river revival. International Journal of Environment and Climate Change. 2020;10(12):202-210.

22. Brugger F. Mobile applications in agriculture. Basel, Switzerland: Syngenta Foundation; 2011.
23. Chaovalit P, Surasvadi N, Pongnumkul S. Applications of smartphone-based sensors in agriculture: a systematic review of research. (P. Siciliano, Ed.) Journal of Sensors; 2015.
24. Bhaskar G, Murthy L, Sharma VP. Mobile Apps Empowering Farmers. Extension Digest. 2017;1(2).
25. Shaikh T. Impact of mobile application in agriculture: Attitude of farmers towards the usage and the problem in accessing the mobile apps; 2017.
26. Ahmed F, Pasha R, Prathap V, Pasha A, Kumari D. Survey on Precision Farming using Mobile Applications. Global Journal of Computer Science and Technology 2018, 18(1).
27. Mane SG, VKR. Review on: Design and development of mobile app for farmers. International Journal of Trend in Scientific Research and Development. (IJTSRD); 2019.
28. Kumar SA, Karthikeyan C. Status of mobile agricultural apps in the global mobile ecosystem. International Journal of Education and Development using Information and Communication Technology. 2019;15(3).
29. Mandi K, Mandal R. Mobile apps in agriculture: A boon for farmers. Agriallis. 2020;2(1).
30. Raj S, Darekar A. Farming 2.0: Digitising Agri Value Chain. Kurukshetra. 2020;69(2).
31. Saxena P. Breaking the digital frontier in agriculture with mobile apps; 2020.
32. Trivedi A, Awasthi MK. Runoff estimation by integration of gis and scs-cn method for kanari river watershed. Indian Journal of Ecology. 2021;48(6):1635-1640.
33. Trivedi A, Gautam AK. Hydraulic characteristics of micro-tube dripper. Life Science Bulletin. 2017;14(2):213-216.
34. Trivedi A, Verma NS, Nandeha N, Yadav D, Rao KVR, Rajwade Y. Spatial data modelling: Remote sensing sensors and platforms. Climate resilient smart agriculture: Approaches & Techniques. 2022;226-240.
35. Korreck S. The Indian startup ecosystem: Drivers, challenges and pillars of support. ORF Occasional Papers; 2019.
36. Ohlan M. Agri-Startups and agribusiness for the development of agriculture in Maharashtra. Hyderabad: National Institute of Agricultural Extension Management (MANAGE); 2020.
37. Rao SD, Chingale R. Software Patent in India: A Comparative Judicial and Empirical Overview. NISCAIR Online Periodicals Repository; 2015.
38. Sodhani S. India: Is Software Patentable In India?
39. Sharma M. Patents for Softwares, SAAS, and Apps in India; 2021.
40. Williams K, Chatterjee S, Rossi M. Design of emerging digital services: A taxonomy. European Journal of Information Systems. 17;2008.
41. Leimeister JM, Österle H, Alter S. Digital services for consumers. Electron Markets; 2014.
42. Scott K. Digital Products vs. Services: Choosing the Right Strategy for Your Online Business; 2018.
43. Choudhary SK, Jadoun RS, Mandoria HL. Role of cloud computing technology in agriculture fields. Computer Engineering and Intelligent Systems. 2016;7(3):1719-1863.
44. Biberacher J. Autonomous Driving, Big Data, Drones: The digital future? Today's technology in farming!
45. Elijah O, Rahman TA, Hindia MN, Orikumhi I, Leow C. An overview of internet of things (IoT) and data analytics in agriculture: Benefits and challenges. IEEE Internet of Things Journal; 2018.
46. Kapur R. Usage of technology in the agricultural sector; 2018.
47. Trendov NM, Varas S, Zeng M. Digital technologies in agriculture and rural areas. Rome: Food and Agriculture Organization of the United Nations; 2019.
48. Anwar U, Noor H, Malik BH, Ali HW, Muzaffar I, August. Applications of Cloud and IOT Technology for the Development of Agricultural Sector. International Journal of Scientific & Technology Research. 2020;9(8).
49. Farooq MS, Riaz S, Abid A, Umer T, Zikria YB. Role of IoT Technology in Agriculture: A Systematic Literature Review. Electronics; 2020.
50. Kour VP, Arora S. Recent Developments of the Internet of Things in Agriculture: A Survey. IEEE Access; 2020.
51. Pawar SC. New Era in Agriculture: Cloud Computing and its Services. Food and agriculture organization of the United Nations. 2020;9(7).

52. Talaviya T, Shah D, Patel N, Yagnik H, Shah M. Implementation of artificial intelligence in agriculture for optimization of irrigation and application of pesticides and herbicides. Artificial Intelligence in Agriculture 2020;4:58-73.
53. Trivedi A, Singh BS, Nandeha N. Flood Forecasting using the Avenue of Models. IJISET - International Journal of Innovative Science, Engineering & Technology; 2020;7 (12):299-311.
54. Blommestein N, Krogt SV, Lamoureux L, Morrow K, Neuman F. ICTs for agricultural livelihoods. International Institute for Communication and Development; 2006.
55. Ayappan S. Vision 2050. New Delhi: Indian Council of Agricultural Research; 2015.
56. Belakeri P, Prasad CK, Bajantri S, Mahantesh MT, Maruthi ST, Rudresh GN. Trends of Mobile Applications in Farming. International Journal of Current Microbiology and Applied Sciences. 2017;6(7).
57. Beriya A. Digital Agriculture: Challenges and Possibilities in India. CSD Working Paper Series; 2020.
58. Bernat L, Bourassa F, Brocca J, Calvino F, Criscuolo C, De Backer K. Key Issues for Digital Transformation in the G20. OECD; 2017.
59. Birner R, Daum T, Pray C. Who Drives the Digital Revolution in Agriculture? A Review of Supply-Side Trends, Players and Challenges.
60. Categorisation of Farmers. Retrieved from Press Information Bureau; 2019. Available:https://pib.gov.in/Pressreleaseshare.aspx?PRID=1562687
61. FAO. Information and Communication Technology (ICT) in Agriculture; 2017.
62. Ingram J, Maye D. What Are the Implications of Digitalisation for Agricultural Knowledge?
63. Mikhailov A, Camboim GF, Reichert F. Identifying how digital technologies are being applied in agribusiness value-chains; 2019.
64. Trivedi A, Gautam AK. Temporal Effects on the Performance of Emitters. Bulletin of Environment, Pharmacology and Life Sciences. 2019;8(2):37-42.
65. Trivedi A, Gautam AK. Decadal analysis of water level fluctuation using GIS in Jabalpur district of Madhya Pradesh. Journal of Soil and Water Conservation. 2022;21(3):250-259.
66. Trivedi A, Gautam AK, Pyasi SK, Galkate RV. Development of RRL AWBM model and investigation of its performance, efficiency and suitability in Shipra River Basin. Journal of Soil and Water Conservation. 2020;20(2):1-8.
67. Trivedi A, Gautam AK, Vyas H. Comparative analysis of dripper. Agriculture Update TECHSEAR. 2017;12(4): 990-994.
68. Trivedi A, Pyasi SK, Galkate RV, Gautam VK. A Case Study of Rainfall Runoff Modelling for Shipra River Basin. Int. J. Curr. Microbiol. App.Sci Special. 2020;11:3027-3043.
69. Trivedi A, Pyasi SK, Galkate RV. Estimation of Evapotranspiration using CROPWAT 8.0 Model for Shipra River Basin in Madhya Pradesh, India. Int.J.Curr.Microbiol.App.Sci. 2018;7(05): 1248-1259.
70. Trivedi A, Pyasi SK, Galkate RV. A review on modelling of rainfall – runoff process. The Pharma Innovation Journal. 2018;7(4):1161-1164.
71. Trivedi A, Nandeha N, Mishra S. Dryland Agriculture and Farming Technology: Problems and Solutions. Climate resilient smart agriculture: Approaches & Techniques. 2022;35-51.

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