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Present status and future prospects of digital transformation of Indian agriculture sector: A review

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Abstract
The following paper involved nine basic categories under which a number of research-based documents were reviewed to gain an in-depth understanding of each category, with the end-goal of understanding the journey of digital transformation of Indian Agriculture sector. A need to interconnect the agriculture value-chain consisting of different players like farmers, processors, wholesalers, retailers, traders, consumers was found through the course of this study, which only demarcates the importance of digital technologies and how they can create much more holistic and sustainable value-chains. The dominance of information exchange and capacity building related technologies is reflected, where technologies like drones, agricultural robots are still few decades ahead for Indian farmers with their low economic backgrounds and lagging literacy rates. Mobile phones and smartphones are found to be changing the shape of Indian agriculture, wherein most technologies are being delivered via mobile applications, which are easily understandable as well as cheaply available. Also, most technologies are being delivered in the form of digital services due to their flexible nature and a long-term association with farmers. Artificial Intelligence, Big Data Analytics and Internet of Things are some technological deliverances which are finding or expected to find maximum applications among Indian farming populations. A number of challenges in the way of digital transformation of Indian Agriculture are language barriers, infrastructural unavailability, Lack of enough government support, low economic backgrounds and high illiteracy rate among Indian farmers, a prevalent digital divide in India. The future of digitization is looking bright for Indian Agriculture sector with a greater number of investments flowing into this sector as privatization and contract farming find a well-supported ground on Indian soil.

Keywords: digital, ICT, agriculture, technology, artificial intelligence, big data analytics, IoT

Introduction
India is a country with great dependence on Agriculture as a source of livelihood, with over 58 percent of rural households involved with this sector for their income source. Gross Value Added (GVA) by agriculture, forestry and fishing was estimated at Rs 19.48 lakh crore (US$ 276.37 billion) in FY20 (PE). The stake of agriculture and allied sectors (including agriculture, livestock, forestry and fishery) is estimated to be 16 per cent of the Gross Value Added (GVA) during 2018-19 at 2011-12 prices (Biswas & R., 2020) [10].

Even though the share of agriculture in Indian Economy is declining due to the continuous growth of Industry and Service-based sectors, the relevance of agriculture cannot be diminished considering the rate of increase in population in this country. What is more probable is the fact that the trends that were seen in the food and consumption patterns in India are bound to change as more and more people migrate to big cities. And as the rest of the country shifts towards digital means, agriculture as a sector too, is liable to encounter digital transformation to match the pace of its consumers.

Digital Technologies like Artificial Intelligence, Internet of Things, Big Data Analytics, Satellite Imagery and Remote Sensing, Machine Learning, Unmanned Aerial Vehicles (Drones) and Robotics are finding major applications in Agriculture Sectors belonging to countries like USA, Australia and Israel. India too is making space for such technologies with changing consumer behaviours and demands, but is still at a very niche stage of this change.

The average farm size in India is 1.08 Hectares and around 80 percent of farmers in India belong to the small and marginal category with access to small land holdings. This creates a lack of demand among Indian farmers for more advanced technologies like farm robots, drones etc. The current trends in India still suggest the information exchange and capacity building based technologies are the most dominant among farmer populations of India, most of which

are delivered through mobile applications and other mobile based services. Such technologies, since not as expensive and technologically advanced, are much suited considering the literacy and financial background of most farmers in India.

This trend in technology adoption, although different from other countries, reflect a positive growth in the journey of digital transformation of Indian Agriculture. This can be established by a report published by the World Bank titled 'What's Cooking: Digital Transformation of the Agri food System', in 2014, according to which the average number of data points produced per farm, per day was 190,000. And by 2050, each farm has been predicted to produce 4.1 million data points per day according to the experts. Such a large number of data points, when analysed and disseminated as information, can prove invaluable for the farmers in terms of production as well as finding target markets to sell their produce.

The recently introduced laws brought about by the government of India, commonly known as farm laws, are somehow reflective of the government's intentions of attracting more investments and money flow towards future advancement of Indian Agriculture. As privatization will be introduced in Indian farming system, digitization will not be further away considering the volume at which agriculture products are consumed in India. Also, attempts like contract farming are well in line with the changing food demands of modern consumers, and therefore interconnected agriculture value-chains where not only farmers, but all the other value-chain players like processors, input suppliers, traders, consumers are digitally empowered and are involved in information related as well as other possible transactions with each other so as to deliver what is actually demanded by the market(Beriya, 2020) (Madan, et al., 2020).

Agriculture value-chain analysis

Boehlje *et al*. (1999) [12] explained in their paper the critical dimensions of structuring an agricultural value-chain, where the first and foremost task is to analyse the value creating activities of the production and distribution process which will ultimately create attributes in the end products to make them sellable to the consumers. This is followed by considerations like product-flow, cash-flow, information-flow, incentive systems in order to reward performance and governance system.

Kumar *et al*. (2011) [30] highlighted in their article the importance of knowledge transfer, and how it needs to be properly modelled serving the specific need of farmers so as to build upon their previously gathered bundle of knowledge. Also, the dissemination of information has to be such that it is clear and to the point, keeping in consideration all the language, cultural and other related barriers offered by farmers in India in order to build trust and increase dependability of farmers on such technological models.

Other than that, considerations of right time to transfer information based on the nature of that particular piece of information, say at the time of production or emerging financial needs, and the correctness of information with proper steps and guidelines for implementation of the same are of great importance. Neven (2014) [41] highlighted in his report four core areas to be included in an agriculture value-chain, namely production, accumulation, post-harvest processing and delivery or distribution. He also classified the value-chain on the basis of three major economic functions, namely input delivery, financial access and service delivery.

Kumar *et al*. (2016) [31] highlighted in their paper that there is a general lack of proper coordination between different members of the agriculture sub-systems. Bridging that gap will bring much more structure and profits to all the areas in the agriculture value-chain. FAO (2017) [20] highlighted in their report the different areas of agriculture value-chain finding major applications of digital technologies, namely training and empowerment, traceability, market access, financial access, environment sustainability, extension activities, expert advisory services and government and policy-based regulation activities.

Mattern *et al*. (2017) [36] presented in their report that farmers and other players involved in the agriculture value-chain have switched to digitized value-chain finance, which are financial services flowing towards or entering from any point of the value chain to provide the members with financial options like insurance, working capital or investment financing required to improve upon the growth of those involved in the said value-chain. Going digital in terms of attaining financial assistance has improved the efficiency of such transactions removing probable barriers and increasing the overall market opportunities.

Saidu *et al*. (2017) [50] highlighted in their paper the findings of different researchers on how ICTs allow access to information, capacity building, market, credit and interconnectivity among different value-chain actors. Shukla *et al*. (2018) [56] pointed out in their report that most Agri start-ups offer big data, AI and IoT based solutions in the value-chain.

Jouanjean (2019) [25] expressed in her report that a continuous flow of information throughout the agriculture value-chain by way of digital tools keeps all the players involved in this process updated about various practices taking place, and the probable actions that might be taken based on the data-driven predictions thereof. These can be related to herd management, farm management, target markets, probable price points, transportation activities etc.

Mikahilov *et al*. (2019) [37] highlighted in their paper that any value-chain can undergo a fundamental change appearing in its dynamic structure with the emergence of new technological options at any point in time. Considering this fact, in case of agribusinesses, the agriculture value-chain was divided in three sections, namely before-the-farm, inside-the-farm and after-the-farm. Out of these three defined categories, most agtechs (around 77%) were found to be serving issues arising inside the farm. 14% agtechs were focussed on after-the-farm solutions, whereas only 9% were focussed on before-the-farm activities.

Nagesh (2019) [39] highlighted in his paper how ICTs not only empower farmers by way of information, but also increase their level of participation and connectivity among other value-chain members. Also, the amount of risk is decreased whether it is those related to market, price, weather or even technology. Chandra *et al*. (2020) [15] emphasised in their report that there is an urgent need to develop more robust tech-enabled agriculture value-chains for transformational innovations in agriculture, and to provide special benefits for smallholder farmers.

Denis *et al*. (2020) [18] pointed out in their article that with great volumes of data being generated on farmer fields, a digital twin of physical supply chains can be developed where activities like production, storage, warehousing, transportation, marketing can all be managed through data analytics, Users can get customized mathematical algorithms

to assist them with activities like profit maximization, markets to target, inventory optimization, food patterns, etc. which will not only be faster and more efficient, but also will lead to the optimization of inputs and processes both off and on the farmer fields.

Madan *et al*. (2020) [33] presented in their report that most investments in Indian Agritech sector are being directed to the supply chain tech and output market linkage segment. The other areas attracting investors' interests are quality management and traceability and financial services. Ravi Kumar *et al*. (2021) highlighted in their paper that in the advent of the Coronavirus pandemic, digitization of agriculture value-chains has emerged as a necessary action so as to connect the different players involved throughout the value-chains. This will include connecting the customers directly to their growers by allowing services like digital payments to create a more dependable and future-centric form of agriculture.

Capacity building and information exchange

Boehlje *et al*. (1999) [12] described in their article the role of knowledge and information in agriculture is increasing because unlike in the past, 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 forefront. Also, since agriculture is becoming skill based with increased amount of research being dedicated to making it more productive through technologies like precision agriculture, the amount of risk can be controlled only through optimum knowledge and information of the dos and don'ts to ensure the delivery of necessary returns on such serious levels of investment. This also leads to the inference that those who have the right kind of information will automatically be more secure and successful in this industry.

Also, as information is becoming a source of major competitive advantage in this new era of agriculture where information dissemination is not any more controlled by the public sector, private sector entities have a high hand as far as controlling the access to such information is concerned, as well as the decisions related to kind of parties allowed or denied that information in order to regulate competition. Similarly, Miller *et al*. (2013) [38] highlighted in their report the importance of timely information, access to mobile phones, financial inclusion, crisis organization information services among others in building better connected and viable agriculture value-chains.

Fielke *et al*. (2020) [22] concluded in their paper that in the area of agricultural knowledge and advisory services, digitization is meant to bring significant changes in trends, like the increased level of connectivity between different actors of agricultural value-chain with upcoming technology solutions, diversification of transparency in the exchange of information among different actors of the value-chain, need to assort the priorities held by different stakeholders involved in agricultural value-chain as digitization progresses, exchange of agricultural data as a commodity, more private players entering the advisory services based market.

Hrustek (2020) [23] highlighted the role of digital transformation of agriculture in timely dissemination of information, personalized product development based on customer needs, traceability, proper policy implementation and an overall connected agriculture value-chain which leads to an environment-friendly and sustainable form of agriculture.

Farmer access to mobile phones and smartphones

Uphoff (2012) [60] highlighted in his paper that in the last 3-5 years farmers have gained access to internet which allowed better connectivity among different members of the agriculture value-chain. This has allowed ICTs to benefit farmers in a number of ways, some of which include access to markets, information, mobile banking, weather related intelligence among others. Also, use of mobile phones and smart phones among farmer populations has increased allowing easy access to above services without having to spend on computers, laptops and other such heavy hardware components. Other than that, social media applications such as Facebook and services like You Tube are availing cheap and easy mediums to share knowledge in the form of images and such to bring together farmers and others like policymakers, researchers, experts to communicate better.

Yared (2015) [62] highlighted in his paper the importance of mobile financial services, one of the most promising area for agriculture-based mobile applications where governments can reach farmers, especially those from poor background and avail a range of credit facilities to improve their livelihoods.

Belakeri *et al*. (2017) [4] highlighted in their paper how mobile phones have allowed reduction in travel expenditure and timely market information for farmers which is very beneficial especially for perishable commodities. Also, mobile applications being developed for farmers are instilled with features like easy-to-recognize icons which can be understood by farmers that are not digitally literate. Not only this, mobile applications are a complete package of audio, video, graphics, text and animation-based features, making them a highly interactive medium for farmers to keep up-to-date with new developments on the agricultural field as well in the market.

Agriculture based mobile applications

Brugger (2011) [13] described in their report different areas in which mobile applications are applied in the field of agriculture, namely market intelligence, trading facilities, tracking and monitoring of operations, quality control, logistics management, financial services and data surveillance and collection. Chaovalit *et al*. (2015) [16] highlighted the challenges in the development of agriculture-based mobile applications for developing countries, where the level digital literacy and inadequate exposure to software-based services lead to challenges in design and development of correct user-interface.

Since many applications are designed keeping large farmers in light, they are unable to target small and marginal farmers with small land holdings. While designing applications for rural farmers, highly intuitive platforms not completely dependent on text-based interactions. Bhaskar *et al*. (2017) [7] explained in their paper how mobile applications allow dynamic dissemination of information with real-time data about weather, market, seeds, fertilizers, which is usually not possible through services like SMS. This is because such services allow only one-sided conversation, not serving the forever-changing situations of farming communities which require back and forth addressal of problems.

Shaikh (2017) [54] in her paper depicted how out of all the agriculture based mobile applications available in Indian market, most of the apps are available free of cost. Also, most mobile applications are available on Google Play store platform, which is pre-installed in most android-based smartphones. This highlights the ongoing trend in digital

agriculture market where farmers are being targeted to adopt digital connectivity through the cheapest and easiest mediums.

Further into this topic, Ahmed *et al*. (2018) [1] pointed out in his paper that mobile applications which can customize their services according to specific geographical location and field requirements, as well as can give information on diverse topic ranging from production practices to customer preferences, are more likely to find applications among maximum number of farmers. Mane *et al*. (2018) [35] highlighted in their paper that camera and GPS services are the trendiest functions being included in mobile applications nowadays.

Kumar *et al*. (2019) [29] in their paper brought attention to the power of mobile applications in linking distribution networks in the agriculture value-chain consisting of producers, suppliers and buyers and bringing in more transparency and efficiency, which not only reduces the role of middlemen but also decreases the risks of falling prey to a number of scams and administrative pressures. Mandi *et al*. (2020) [34] highlighted in their paper that by 2016, maximum number of mobile applications in the field of Indian Agriculture were based on farm management area of specification.

Other areas of Mobile App development included diseases and pests, market intelligence, agriculture information, skill learning and conference applications. They also pointed out that although a number of barriers related to the usage of mobile applications exist like difficulty to operate and multi-language interface, mobile applications are still a very dependable medium for farmers to connect with the market and access real-time information to achieve better results on their fields. Raj *et al*. (2020) [46] highlighted in their paper how different mobile applications are being developed to bring about a farm-to-fork connectivity in the agriculture value-chain, where different farmers are being connected to their prospective consumers to serve as per their demands and conquer the issues of remunerative prices, wastage and middlemen, all in one go.

Saxena (2020) [51] highlighted in his article that by 2022, the global market value of smart agriculture will be about 23.14 billion US dollars. He also shed light on the benefits of mobile applications for farmers which include ready-to-use guides for farmers within affordable prices working as information disseminators, an easy access to field data being captured by sensors installed for purposes like pest infestation warning, nutrient dose prescriptions and access to GIS (Geographical Information System) services in order to capture soil data for better management and productivity.

The different types of mobile applications in agriculture sector enlisted in this article are concerned with information exchange and connectivity with peers, online lending services, e-marketplaces, weather forecasting, GPS tracking, traceability of value-chain processes and livestock management services. The different features found in these applications are chat options, cloud support, machine learning, payment gateway, information stacks and weather forecasts.

Importance of infrastructure in digital transformation of agriculture

Bernat *et al*. (2017) [6] highlighted in their report the importance of digital infrastructure in allowing a digital economy to set up. They pointed out the role of government administrations in promoting better investments towards building digital infrastructure, like broadband to allow cheaper internet services and a wider internet traffic.

Korreck (2019) [27] depicted that every three out of four IT based employers are situated in Bangalore, the reason being the conducive environment and government backed structure of progressive policies. Also, one in four tech start-ups in India are based in Bangalore, Karnataka. Mumbai being the financial capital of India, is home to many new fintech start-ups. Although in Mumbai and Delhi, the cost of living is higher than that in Bangalore, creating a less start-up friendly culture. Safety and lack of acceptance are also important reasons keeping Delhi behind the above two cities. Chennai too is seen as a hub as far as start-up culture is concerned. Along with that, Tier-1 and Tier-2 cities like Pune, Hyderabad, Ahmadabad, Calcutta are emerging cities being recognized as home by emerging start-ups.

Ohlan (2020) [42] discussed in her report that Agritech start-ups based in Bengaluru raised the maximum amount of funding in year 2016, followed by Delhi in the second position and Mumbai in the third. This highlights the importance of infrastructural connectivity in creating opportunities to expand the digital agriculture Industry in India, be it in terms of roads, electricity or digital connectivity. She also pointed out that among the start-ups that were setup in last five years, 50% of those were started in the years 2015 and 2016.

Difficulty in availing patent for digital technologies

Rao *et al*. (2015) [47] in their article highlighted the limitations of Indian Patent Act which clearly states that a computer program by itself is not patentable, unless it comes with hardware components without which it can't successfully function and produce practical results which do not include merely information generation. They also pointed out that the exact categories of software inventions which end up getting patented are not clearly enlisted or defined in the guidelines and hence need proper addressal, especially in the cases of MSMEs and Entrepreneurs. Sodhani (2019) [57] explained in her article that in India, a software can be patented when it is attached to an invention, meaning a hardware component which is an essential constituent of that invention besides the computer program.

Sharma (2021) [55] put forth in his article that in case of availing a patent for mobile applications, the first consideration needs to be about the longevity and sustainability of the business, considering that most apps go out of business in more or less six months, whereas to get them patented at least twelve months are required. Also, to get a software patented, it is important to pay added attention while describing the concerned invention in patent application and making sure that it meets all the technical and legal requisites, for the IPO to consider it in a positive light. Also, since according to Indian patent laws, a software program alone is not patentable, developers can go for copyright protection for their software codes.

Digital services versus digital products

Williams *et al*. (2008) [61] highlighted the current shift in digital marketplace where digital services are preferred more than digital products for development. Leimeister *et al*. (2014) [32] highlighted in their paper that digital services are based on an individual approach, where the needs of particular customers are given prime importance, and reviews and feedbacks are taken in consideration in order to make better delivery in future occurrences. Also, here customers are

benefitted through customized services, whereas service providers are benefitted through customer loyalty.
Scott (2018) [53] in her article established the pros and cons of offering digital products and digital services. She pointed out that while digital products are easy as well as cheap to develop, they are mostly created to serve the masses and do not give a personalized experience to the customers. In contrast to this, digital services allow the developers to create much more personalized deliverances, where they have control over their client's experiences and can fit their offerings as per the specific needs and requirements of their clientele.

Digital technology applications
Choudhary *et al*. (2016) [17] explained in their article how with a decentralized system of data storage, the need to invest in heavy hardware components and outdated methods is brought to minimum. Farmers are allowed an all-day access to their soil-related, weather-related and other kinds of data through devices which have cloud accessibility for farm management and other related purposes. Not only farmers, other players in the system like experts, consultants, researchers can also access this data without having to pay personal visits to the farmers, hence saving a great amount of time as well as resources. The free flow of information, and healthy exchange of services is also possible through such systems, encouraging the overall development of Indian Agriculture.
Biberacher (2018) [8] showed in his article depicted ways in which IaaS, PaaS and SaaS are applicable in the agriculture sector. IaaS applications include high tech farming infrastructure, PaaS applications include technologies like drones, satellites, robots and sensors and SaaS applications include big data analytics, artificial intelligence, information and monitoring software. Also, four steps to digitize a farm are presented in this article, namely installing sensors in the farm, connecting the sensors to a cloud platform or hardware component, using cloud applications to take advantage of artificial intelligence, big data analytics and other analytical services to turn data collected from the field into useful information, and enabling farm equipment to turn feedback and recommendation into real actions.
Elijah *et al*. (2018) [19] highlighted in their paper the use of wireless sensors for the application of IoT and Data Analytics based methods so as to increase the productivity and efficiency of farm activities and bring about smart agriculture. Other than wireless sensors, IoT uses other technologies like radio frequency identification, cloud computing and the like for their application.
Kapur (2018) [26] explained in their paper the diverse applications of Information Technology in the field of agriculture, like for information exchange regarding production practices, market intelligence, post-harvest techniques, consumer preferences, weather forecasting, input availability and credit availability, early warning systems regarding pests, diseases and the like and organizing education and training sessions for farmers through web-based platforms.
Trendov *et al*. (2019) [59] highlighted in their report the increasing number of AI applications in livestock sector for animal identification and other applications like disease control.
Anwar *et al*. (2020) [2] depicted in their paper clear examples of three types of cloud computing models, like tablets, computers, mobile phones for infrastructure-as-a-service type, data bank, operating systems for platform-as-a-service type and web applications and other software for software-as-a-service type of cloud platforms. Also, different applications of cloud computing in agriculture sector are listed as weather information database, pest and disease information database, new technologies and innovations related information database, information exchange database, quality monitoring, real-time crop monitoring.
Farooq *et al*. (2020) [21] explained in their paper that the main domains of IoT application in the field of agriculture are monitoring, controlling and tracking solutions, out of which 70% studies have set their focus to monitoring, 25% to controlling and only 5% to tracking applications. Further classification of these application domains is irrigation monitoring and controlling, precision farming, soil monitoring, temperature monitoring, disease monitoring, fertilization monitoring and other such specializations. Precision farming and irrigation monitoring and controlling applications are covered by the greatest number of studies dedicated to this area of research.
Kour *et al*. (2020) [28] showed the increasing number of applications if Internet of Things in agriculture sector for purposes like farm management, irrigation, crop monitoring, disease monitoring and supply chain management.
Pawar (2020) [43] explained in his paper the different applications of cloud computing in agriculture, like crop data, crop monitoring, soil data, region specific farming data, and agricultural marketing. Where Infrastructure as a Service type of cloud computing are relevant for network architects, Platform as a service type of cloud computing is for application developers, and Software as a service type of cloud computing are developed for end users, especially farmers.
Talaviya *et al*. (2020) [58] explained in their paper the different ways in which Artificial Intelligence is being applied in the field of agriculture. Some of these applications mentioned in this study are image recognition and perception, chatbots, robotics and autonomous systems in the form of automatic plant irrigators, soil moisture sensors, vision-based weed detection technology, weed prevention robots, drone technology applications for pesticide spraying, crop monitoring, yield mapping, yield calculation and the like.
Birner *et al*. (2021) [9] highlighted in their article a clear distinction between two categories of digital technologies, namely embodied and disembodied innovations based on the establishment already made in the field of agriculture economics. Based on this categorization, digital technologies in the field of agriculture can be divided into two main areas, the first being precision farming technologies for both crop as well as livestock applications embodied as physical devices like sensors and machines, and the second being software tools delivered in disembodied forms like online platforms, farm management software, mobile advisory applications.

Opportunities and challenges in the way of digital technology applications
Blommestein *et al*. (2006) [11] highlighted in their report the different ways in which ICT have the capacity to shape the future of farmers. These include providing focussed training, a proper communication channel to exchange information and facilitating the overall reduction of risk factors like bringing ICTs in mainstream areas like policy implementation so as to make farming a futuristic sector with ensured livelihoods.
Ayappan (2015) [3] concluded in their report that in future

there will be a growing number of research collaborations between public entities, CGIAR Institutes, foundations and private enterprises leading to frequent technology development and in turn an increased number of investments coming from the private sector towards agricultural growth.

Chaovalit *et al*. (2015) [16] highlighted the challenges in the development of agriculture-based mobile applications for developing countries, where the level digital literacy and inadequate exposure to software-based services lead to challenges in design and development of correct user-interface. Since many applications are designed keeping large farmers in light, they are unable to target small and marginal farmers with small land holdings. While designing applications for rural farmers, highly intuitive platforms not completely dependent on text-based interactions.

Nagesh *et al*. (2019) [39] highlighted in their paper how language is one of the barriers for farmers belonging to different regions using ICTs for agricultural purposes.

S. *et al*. (2019) [49] claimed how FPOs play an important role in generating value and employment among poor folk, enabling small and marginal farmers to access facilities well in line with the employees of an MSME.

Ingram *et al*. (2020) [24] concluded in their article that increasing the capabilities of digital technologies right from the farm and advisor level to new technology providers in order to achieve the full value of digital technology solutions. Other than that, combined learning and collaborative approaches are the key answers to foster some real changes in the lives of those for whom these technologies are being developed.

Madan *et al*. (2020) [33] highlighted in their report that in comparison with the state of agriculture in countries like Israel, we are still miles behind as far as adoption of more advanced digitized technologies is concerned despite having second largest area of arable land in the world.

Prabhakar (2020) [45] pointed out in his report that by 2030, Artificial Intelligence is going to imbibe each and every part of the Indian Agriculture value-chain with self-mechanized machines and intelligent tools propelling all labour as well as service-based tasks both on and off the field.

Talaviya *et al*. (2020) [58] pointed out in their paper the two major challenges being faced by Indian agriculture sector considering the economic conditions and technical background of Indian farmers. Firstly, the technologies being developed need to be made more robust, so as to fit the unpredictable nature of farming and take real-time decisions in order to meet the flickering demands of an agricultural field. Secondly, the solutions need to be more affordable for an average farmer to access and adopt in his day-to-day activities.

Birner *et al*. (2021) [9] covered in their paper the major challenges that are lying ahead for digital development in the field of agriculture. Some of these challenges are insufficient investments, smaller market size creating friction for businesses to meet their respective development expenditure, high development costs for embodied type of technologies and non-conducive business environment.

Beriya (2020) [5] pointed out two major factors that have made digital transformation of agriculture a possibility in India, namely privatization and the advent of Farmer Producer Organizations. He also claimed that most technologies being developed in India are still based on foreign models, making them non-feasible for Indian farmers. Also, the importance of pay-per-use technologies and renting models is highlighted by the author, and how these frameworks can help Indian farmers, mostly financially weak, to access digital technologies on their own terms. The importance of FPOs in supporting small and marginal farmers technologically as well as financially is also pointed out in his paper.

Payne *et al*. (2021) [44] highlighted in their report the major challenges that the digital development of agriculture has been falling prey to. The challenges are infrastructural shortcomings including telecommunication network, power and electricity, inadequacy of relevant policies and protocols to be regulated by government authorities, an absence of digital skills and literacy among farmer populations, gender biases especially on the ownership and use of mobile phones via women and other cultural reservations concerning digital technology adoption.

Conclusions

Collectively, these studies have shone light upon major trends prevalent in the way of digitization of Indian Agriculture, like the dominance of information and capacity building based technologies, increasing use of mobile applications among farmers, inclination towards digital service development over digital products, importance of infrastructural development, status of patent application and grant among digital technology developers in India, present and future trends of digital technology applications in the form of Artificial Intelligence, Internet of Things, Big Data Analytics among others, and the overall challenges and future prospects in the way of digital transformation of Indian Agriculture sector. Keeping in mind the scope and expanse of digital agriculture and its importance in India, more studies should be reviewed to gain a better understanding of the future of Indian Agriculture sector and how this change can be made smoother and much more efficient for all the stakeholders involved in this sector.

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