**Digital Agriculture and Information and Communication Technology for Ensuring Sustainable Development**

**in India: A Review**

:

## ABSTRACT

|  |
| --- |
| India is described as an agricultural powerhouse on a global scale due to its vast agri-ecological diversity. Even though attaining food adequacy in production, India still faces issues related resource-intensive agriculture and less farmer productivity, raising poverty and malnutrition. The involvement of information and communication technology (ICT) in evolving agriculture has become even more essential. It assists farmers with timely information related to environmental conditions, soil health, and crop management and beyond it, where it has the potential to stimulate growth in agricultural productivity and promote sustainable farming through informed decision-making and resource management. This paper reviews the relevance of ICTs in farming for rural development, food security, and resilience. Newer technologies such as 5G, AI, and cloud computing provide exciting new possibilities to explore for a robust vision for Indian agriculture that is organised, data-oriented, and productive.  It can stimulate economic development through improved access to markets and knowledge sharing, with ICT playing an important role in supporting rural communities. However, challenges such as limited connectivity and low digital literacy must be addressed to facilitate widespread adoption of ICTs. ICT in agriculture draws parallels to the "Third Green Revolution," where there is a need to strive towards more affirmative inclusion of small farm households and women, especially amongst developing countries.Enhancing the agenda of sustainability through ICT and sustainable practices will be a major strategy in creating ecological balance, environmental health, and resilience for agricultural systems for the future. |

*Keywords: Information communication technologies; sustainable farming; agriculture; rural development; artificial intelligence.*

## 1. INTRODUCTION

Agriculture is the predominant economic activity in rural areas of developing countries (Capozucca, Sarni, & krause, 2012) (Torero, 2014). Its therefore offerings the greatest potential to decrease poverty, improve food security and usually advances the livelihoods of rural people (Mohamad & Gombe, 2017) (The World Bank, 2018) Communication, information exchange, transactions, and knowledge transfer are essential in almost each aspect of agriculture (El Bilali & Allahyari, 2018; Sharma & Bhambri, 2025). In recent years, ICT has appeared as a transformative tool, bringing forth game-changing agricultural innovations. ICT has revolutionised the sector by offering solutions such as sensor networks, data analytics, satellite imagery, and mobile applications. These technologies have provided farmers with access to timely, location-specific information, enabling them to make better decisions, optimise resource usage, and adopt sustainable practices. ICTs permits the storage, capture, processing, transmission, retrieval, and shown of various forms of information, along with video, graphics, text, images, animations, etc. This suggests a considerable improvement in conveying almost entire information necessities inside the realms of agriculture and development procedures (Mukherjee et al., 2025). The integration of ICT in agriculture is frequently referred to as e-agriculture, a rapidly growing field aimed at empowering farmers through digital solutions (Kshetri, 2014). India is described as an agricultural powerhouse on a global scale due to its vast agri-ecological diversity. Agriculture is a foundation of the Indian economy, being approximately 18% of GDP and nearly 45% of the personnel population (Redseer Strategy Consultants, 2023). After becoming developed, the agritech ecosystem has the potential to increase the incomes of Indian farmers by 25 to 35% and devoted US$ 95 billion to the country's GDP via lower input costs, augmented productivity, price realisation, more reasonable finance, and supplementary sources of income (NITI Aayog). India has follows agricultural self-sufficiently from gaining independence. Whereas achieving food sufficiency in production, India still faces issues about low farmer productivity and resource-intensive agriculture, outcoming in poverty and malnutrition. Agriculture engage around half of the country’s labor force and uses three-fourths of the country’s freshwater resources; nevertheless, it contributes only one-sixth of the GDP (Lajoie-O'Malley et al., 2020). This indicates low worker productivity and ineffective resource consumption in India's agriculture industry. This is due to the realization that the majority of agricultural output is produced by small-scale family farmers and stock breeders who lack the resources and technological assistance required to increase farm efficiency. Ernst & Young Report, 2020. Press Bureau of India (PIB), India ranked 8th with a segment of 2.33% amongst the world's peak agricultural exporters. Along with, Ernst & Young's report displays that agritech firms in India confirms a US$ 24 billion opportunity, though the market is still mostly untapped (with only 1.5% penetration). Also, Agritech firms in India exhibits a US$ 24 billion opportunity, though the market is still typically untapped (with only 1.5% penetration). Among 2020 and 2027, the universal agritech industry is probably to grow at a compound annual growth rate (CAGR) of 12.1% (Ernst & Young Report, 2020).

Despite these advancements, challenges remain. Connectivity issues, low computer literacy among rural farmers, and the disintegration of markets continue to hinder the widespread adoption of ICT. Moreover, small and marginal farmers, who constitute over 86% of India's farming community, often struggle to access these technologies. The average farm size in India is only 1.08 hectares, making it difficult for farmers to invest in advanced technologies (Shetty & Philip, 2022). To alleviate these challenges and enhance ICT adoption further, numerous initiatives have been taken by the Indian government that function on multiple dimensions. These include water use efficiency, better crop seeds, diversification of livelihoods by improving the scope of rotation of crop plants, and soil health management as a part of NMSA. Also, by increasing the budgetary allocation, their initiatives promote and engage resource usage in a combined manner with the espousal of technologies using drones, artificial intelligence, etc (AG Horizon Group Pvt. Ltd., 2023). In India's agricultural sector, ICT holds immense potential to drive sustainable development, enhance productivity, and improve the livelihoods of millions of farmers. This section explores the transformative impact of ICT on Indian agriculture, highlighting its role in promoting inclusive growth and fostering rural development, Through the use of progressive technologies including 5G, artificial intelligence (AI), cloud computing and blockchain India's agricultural landscape is on the verge of a digital revolution that could ensure a more resilient, data-driven, and sustainable future for the sector.

Indian agriculture is now independent and a chief exporter of agricultural harvest. India is the first, second, or third foremost producer of countless agri-commodities worldwide. Yet, Indian agriculture is founded with several handicaps. The primary challenges faced by the Indian agriculture sector are smallholder farmers, absence of reach of Farmer-Producer Organisations (FPOs), scarcity of Agri data, and conflicts of actual value awareness by farmers. The regulated market model (mandi) shows obstacles such as shortage of such hubs, steep operational costs, and absence of clarity in pricing formulation (Adhya & Sahoo, 2022). Information and communication technology (ICT) aids offer up-to-date information on the market prices of consumer trends, commodities and inputs, which ultimately can enhance a farmer's negotiating position and their livelihood. A key facet of ICT is the accurate information should reach the farmers at the right time to make more sustainable use of on-farm resources. ICT is going to play a bigger role in agricultural extension as well as private sector market intelligence, agribusiness and market information,. Rohila et al found out the role of ICT not only in delivering greater awareness and knowledge in agriculture technology and information but also in terms of farmers’ attitudes towards trying to adopt new technologies (Rohila, Yadav, & Ghangh, 2017). For the definition, background, and directions for future study in this area, Spanaki et al. provided a single normative reference for more analysis and involvement in the agritech environment. According to the findings, operations research on agritech and the disruptive potential of AI in the agriculture sector is still in its infancy. In addition to providing a research agenda for a developing subject with several potentialities for the future of agricultural operations, they hope that the systematic review will educate a broad spectrum of agricultural stakeholders, including farmers, agripreneurs, academics, and practitioners (Spanaki, Sivarajah, Fakhim, Despoudi, & Irani, 2022). Additionally, Ganesh kuma et al in their study examine artificial intelligence (AI)-based product benefits and problems of the agritech industry. Results show that better information for quicker decision-making has been graded as the uppermost AI benefit. This infers that the executives of agritech units are in trouble about the quality of decisions they make, and resistance to alteration from employees and internal culture has been graded as the uppermost AI problem (Ganeshkuma, David, & Jebasingh, 2022). Still Blockchain technology, challenged with vital limitations, it is a transformational information and communications technology (ICT) that has altered our notion of trust. Improved efficiencies for agricultural sustainable development have been recognized when ICT-enabled farms have gain knowledge banks and other digital resources. ICT e-agricultural systems with blockchain infrastructure are complete and distributed ledger systems for record management; baseline agricultural environmental data integrity is safeguarded for those who participate in transparent data management. The model of the ICT e-agriculture system with a blockchain infrastructure is projected for use at the local and regional scale. To determine context-specific technical and social necessities of blockchain technology for ICT e-agriculture systems, an evaluation tool is available. The proposed system and tool can be assessed and applied to further developments of e-agriculture systems (Lin, et al., 2017).

Chowhan and Ghosh found that the use of ICT-based services in agriculture is currently very low, mainly due to limited access, high costs, and lack of training. It suggests that solutions like IT-based training, affordable ICT tools, better internet and electricity infrastructure, and the adoption of advanced technologies (such as AI, IoT, and big data) are essential for improving agricultural productivity and sustainability (Chowhan & Ghosh, 2020). The Indian agriculture sector is rapidly adopting innovative technologies such as IoT and other advanced tools, with both Indian and foreign agritech companies playing a crucial role in this transformation. These advancements are essential for boosting India's agricultural growth and are reshaping the industry for the benefit of farmers, society, and all stakeholders (Anajli, Yadav, & Priya, 2023). The NSSO survey estimated that there were 93.094 million agricultural households in rural India, representing roughly 54% of all rural households which includes a significant portion (70.4%) of agricultural households possessed less than one hectare of land, while a very small percentage (0.4%) held more than 10 hectares (National Sample Survey Office, 2022). Patil et al., evaluates the Indian scene suggests that market information and weather updates are of prime interest; illiteracy, cost and lack of awareness are the major adoption constraints. Human capital enhancement was understood to be the main remedial factor to change the low rate of ICT adoption and its effectiveness (Patil, et al., 2008). The use of drones in agriculture offers significant benefits, including higher efficiency, reduced operational delays, and lower costs for spraying and fertilizer application. Drones also minimize wastage of inputs, save water, and reduce farmers’ exposure to hazardous chemicals compared to traditional methods (Press Information Bureau, 2022). ICT has the potential to revolutionize Indian agriculture by providing timely information, precision farming tools, and improved market access, yet many projects remain at the pilot stage and widespread breakthroughs are still lacking[5](https://iipseries.org/assets/docupload/rsl20244E0330B2B1FB571.pdf)[6](https://epubs.icar.org.in/index.php/IndFarm/article/download/165715/59652/457860). There is an urgent need to evaluate, compare, and scale up ICT initiatives to ensure farmers receive accurate information and benefit from advanced digital technologies (Singh, Ahlawat , & Sanwal, 2017).

**Table 1. Effect of technological intervention on foodgrain production (in million tonnes)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Year** | **2017-18** | **2018-19** | **2019-20** | **2020-21** | **2021-22** |
| Production of food grains | 285.01 | 285.21 | 297.50 | 310.74 | 315.72 |

*Source: Ministry of Agriculture & Farmers Welfare; https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1884*

## 2. RESEARCH GAP

Present studies highlight the transformative role of ICT in agriculture, mainly its potential to augment productivity, sustainability, and farmer livelihoods. However, gaps remain in the extensive adoption of these technologies, particularly among smallholder farmers who constitute the majority of India’s agricultural workforce. Significant challenges such as low computer literacy, poor connectivity, and limited access to advanced technologies hamper progress, despite the potential economic benefits of agritech solutions. Besides, while technologies like AI and blockchain are familiar for their potential, their adoption remains limited due to technical, cultural, and infrastructural barriers. Moreover, in terms of sustainability, the incorporation of ICT into agriculture has not adequately addressed the longer-term environmental challenges. During a time when ICT provides tools devoted to improving productivity and resource management among farmers, there is not enough research devoted to understanding environmental resilience, sustainable use of resources and environmentally friendly practices, or the relationships with smallholder and marginal farmers. Simultaneously, the integration of ICT into agronomic systems and/or sustainable agriculture systems is still largely unexplored, providing opportunities for continued research into how technologies can address the environmental challenges.

## 3. UTILISING TECHNOLOGY 4.0 FOR A SUSTAINABLE AGRICULTURAL REVOLUTION IN INDIA

India is headed towards the era of Agriculture 4.0 with the effective participation of digital farming techniques and integration of advanced technology such as data analytics, drones, AI, ML and robotics to transform the outdated Indian agriculture ecosystem. The increasing innovation ecosystem has carried uncountable growth opportunities for farmers to take advantage of technology for their gain. As per the report of WWF India, through innovative interventions in repulsing 86% of animals, a 60% surge in crop production has been recorded, where agri-tech startups have engaged in a major role.

The government, introduced several schemes and initiatives which includes as the AGNIi Mission and National e-Governance Plan in Agriculture (NeGP-A), is eagerly capturing the new setups and innovation ecosystem of the nation to upsurge crop yield and agricultural productivity and sustainably. As per the NITI Aayog report, the adoption of artificial intelligence in the Indian agriculture sector is projected to attain a total growth of 22.5% CAGR during the years leading to 2025 to become US$ 2.6 Bn. This growth will also have implications for improved cropping, resource-efficient farming practices, and gainful productivity.

The Economic Survey of 2022-23 also mentions over 1000 agri-tech businesses, which have propelled the Indian agriculture industry to 4.6% growth over the previous six years. Growing business and livelihood prospects in the agriculture and rural sectors are being facilitated by the continuous improvement of agricultural infrastructure. To report on the growing problem of food security, the digitisation of Indian agriculture will play a crucial role and enable Indian farmers to impact the potential of technology to enhance sustainability.

(AG Horizon Group Pvt. Ltd., 2023).

* 1. **Role of ICT in Indian Agriculture**

Information and Communication Technology (ICT) provides a backbone for reforming and digitising agriculture. ICT provides several solutions to enhance agricultural productivity, market access, and sustainability, including decision-making support and enhancing crop marketing. By using web and mobile applications and all digital tools, ICT enables farmers to receive timely, relevant information to improve farm operations. ICT does this by providing real-time future forecasts, current market prices, and expert opinions so that farmers can make informed decisions around crop choice, when to plant, and market approach. This, in turn, has contributed to higher yields and better income for farmers. ICT includes all the technical tools to handle information and facilitate communication. ICTs are increasingly being used to disseminate information to farmers. Radio and TV programs both feature agricultural information. Due to their allure and widespread use, information and communication technologies have a significant impact on the rural economy (Dutta & Anand, 2023).

Below are some of the key roles of ICT in agriculture:

1. **Decision Support System:** ICT tools empower farmers by delivering real-time, localised data on weather, crop varieties, and soil conditions. This helps farmers make informed decisions at each stage of farming, from crop selection to post-harvest, improving resource efficiency and productivity.
2. **Expanding Market Access:** Digital platforms connect farmers directly with buyers and markets, reducing reliance on middlemen. This allows farmers to access better prices, widen their customer base, and stay informed about market demand, enhancing their revenue.
3. **Empowering Farming Communities:** ICT fosters collaboration among farmers, institutions, and experts. It provides access to updated knowledge on agricultural practices and innovations, allowing farmers to improve techniques, share experiences, and strengthen community networks.
4. **Access to Information:** Through mobile apps and SMS services, farmers receive timely updates on weather, pest control, and market prices, allowing them to adapt quickly to changing conditions and make proactive decisions that boost productivity.
5. **Precision Agriculture:** By utilising data from sensors and drones, farmers can manage resources like water and fertilisers with pinpoint accuracy. This leads to more sustainable farming, lower costs, and improved yields while minimising environmental damage.
6. **Financial Inclusion:** ICT enables access insurance, to digital financial services, helping farmers secure credit, and subsidies. This empowers them to invest in modern technologies and improve their livelihoods.
7. **Data Analytics:** ICT systems analyse vast amounts of agricultural data, providing farmers with insights into soil quality, crop health, and yield predictions. These insights help manage risks, improve decision-making, and enhance productivity.
8. **Climate Resilience:** ICT tools offer early warning systems for extreme weather, helping farmers take precautionary measures. This promotes climate-smart agriculture, allowing farmers to adapt to and mitigate the impacts of climate change.
9. **Supply Chain Management:** ICT improves transparency and coordination across the, reducing waste, agricultural supply chain improving product quality, and ensuring efficient logistics from farm to market.
10. **Capacity Building:** Online training programs and virtual resources equip farmers with new skills, keep them updated on technological advancements, and offer expert advice, helping them stay competitive and innovative.
11. **Policy and Governance:** Governments use ICT to efficiently implement agricultural policies, distribute subsidies, and monitor sector performance. This ensures that farmers receive the necessary support for growth and development.

## 4. CHALLENGES IN IMPLEMENTING ICT IN INDIAN AGRICULTURE

Implementing ICT in Indian agriculture holds significant potential to transform the sector. However, the process is fraught with challenges that limit its widespread adoption. Below are the key challenges derived from reports and research by Indian agricultural organisations:

1. **Connectivity and Infrastructure Gaps:** Many rural areas, especially in states like Jharkhand and the North East, lack reliable internet, limiting farmers' access to ICT tools. Significant investments in rural infrastructure are required to enhance connectivity.
2. **High Initial Costs:** The high upfront costs of ICT tools like drones and sensors deter small-scale farmers, particularly in states like Bihar and Uttar Pradesh, where financial support and access to credit are limited.
3. **Low Digital Literacy:** Many farmers, especially in Odisha and West Bengal, lack the digital skills needed to use smartphones and online platforms. Training programs are essential to bridge this gap.
4. **Data Privacy and Security:** Concerns about data misuse deter farmers from adopting data-driven technologies. This issue is prominent in states like Punjab and Haryana, where trust in data privacy needs improvement.
5. **Fragmented Land Holdings:** Small, fragmented land plots, common in states like West Bengal and Kerala, complicate the adoption of precision farming technologies that require larger, uniform fields.
6. **Tailored Solutions for Smallholders:** Most ICT solutions are designed for large-scale farming and do not address the specific needs of smallholders, such as localised weather data and crop management practices.
7. **Limited Awareness and Trust:** Many farmers are unaware of the benefits of ICT, and there is a lack of outreach to promote its use. Scepticism about the accuracy of ICT tools further limits adoption.
8. **Insufficient Government Support:** While the government has introduced initiatives like Kisan Call Centres, a lack of coordination between agencies leads to fragmented implementation. More integrated policy frameworks are needed for effective ICT deployment in agriculture.

## 5. ICT INITIATIVES IN INDIAN AGRICULTURE

India has made significant strides in integrating information and communication technology (ICT) into agriculture, with both government and private entities introducing various digital platforms, tools, and services to empower farmers. These initiatives aim to enhance productivity, improve market access, and provide critical information to farmers.

The Indian government is also promoting sustainable agriculture through a variety of measures, including improved crop seeds, livelihood diversification through crop rotation expansion, water usage efficiency, and soil health management as part of NMSA. With increased financial allocation, the government is also pushing resource utilisation in an integrated way through the adoption of technology such as drones and artificial intelligence. According to the statistics, India carried out 45% of the world's ICT projects. In addition, rural India has the highest concentration of information kiosks in Asia. However, the majority of rural ICT initiatives are carried out in South and North India's socioeconomically advanced states (Saravanan, 2012). Several Agricultural initiatives in India are mentioned below.

**Table 2. Agricultural initiatives in India**

| **S. No.** | **Projects/Web Portals** | **Description** |
| --- | --- | --- |
| **Web Portals** | | | |
| 1. | aAQUA | Online Indian farmer knowledge exchange which answers questions of farmers in 4 languages in 420 districts in India and Abroad with 7,674 posts, 3.3 million views by 12,964 viewers (www.aaqua.org). |
| 2. | KISSAN Kerala | It is a multimodal agriculture information system for Kerala to support better land and water management. It helps in Tele-advisory, SMS, Online information, video channel, and GIS-based agro-services (www.kissankerala.net). |
| 3. | TNAU AGRITECH Portal | Dynamic portal and e-linkage with research stations and the farm sciences centre for agro-advisory services (www.agritech.tnau.ac.in). |
| 4. | AGRISNET | Agriculture resources Information System Network, a mission-mode project sponsored by the Ministry of Agriculture to nurture online knowledge portals (multiple state-specific portals). |
| 5. | DACNET | 46 websites and 39 applications for crop information, extension services, and more (www.dacnet.nic.in). |
| 6. | e-Krishi | Collective initiatives that use ICT for agriculture and rural development provide market information, a resource library, Web-based farm advisory services and online expert advisory (www.ekrishi.org). |
| 7. | ASHA | Agricultural information for Assam farmers (www.assamagribusiness.nic.in). |
| 8. | India Development Gateway (InDG) Portal | Multilingual portal for agriculture and rural information for rural communities, Dispersed content management system by 225 institutional, Private, NGO’s Government support (www.indg.in). |
| 9. | Rice Knowledge Management Portal (RKMP) | Comprehensive rice information portal with an e-learning platform for farmers, extension personnel, and researchers (www.rkmp.co.in). |
| 10. | Agropedia | Agricultural knowledge repository built in a collaborative mode in multiple languages, hosting over 9,000 pages till date (agropedia.iitk.ac.in). |
| **Web Portals for Market Information and Agri-Business Firms’ Portal to Farmers** | | | |
| 11. | AGMARKNET | Portal launched to connect agriculture produce markets, State Agriculture Marketing boards and directorate of Agriculture Marketing all over India (www.agmarknet.nic.in). |
| 12. | ITC-e-Choupal | Initiative helps farmers to provide access to information and services, reaching 4 million farmers in 40,000 villages (www.echoupal.com). |
| 13. | EID Parry- Indiagriline | Provide agricultural services to rural peoples in all over in India, (www.eidparry.com/agriland.asp). |
| 14. | Indiancommodities.com | Agricultural collateral management companies working in India, Provides Fee-based market information on numerous commodities including oilseeds, cotton, sugar, pulses, etc. (www.indiancommodities.com). |
| 15. | Mahindra Kisan Mitra | Web portal providing information on mandi prices, weather, loans, insurance, agri-news, and more (www.mahindrakisanmitra.com). |
| 16. | IFFCO Agri-Portal | Agricultural services portal in the local language portal and 100 farmer kiosks running in 16 states (www.iffco.nic.in). |
| 17. | Agrowatch Portal | Largest agribusiness portal working on more than 15 sub-sectors of agriculture and food industries (www.agriwatch.com). |
| 18. | iKissan | Crop-specific agricultural information, local agri-news, market data, and diagnostic packages (www.ikisan.com). |
| **VKCs/ VRCs/ CICs/ CSCs** | | | |
| 19. | Village Knowledge Centres (VKCs) - MSSRF | 101 VKCs providing location-specific content and services with 315 partners (www.mssrf-nva.org). |
| 20. | Village Resource Centres (VRCs) – ISRO | 473 VRCs set up in 22 states, providing agricultural, healthcare, and educational services (www.isro.org/scripts/villageresourcecentres.aspx). |
| 21. | Community Information Centres (CICs) | e-Infrastructure for accessing rural information in North-East India (www.cic.nic.in). |
| 22. | Common Service Centres (CSCs) | Provides Digital e-governance services, counting with agriculture information related to soil, crops, cattle, etc (www.csc-india.org). |
| **Telephony/ Mobile Telephony** | | | |
| 23. | Farmers Call Centre (Kissan Call Centre) | 32 call centres, answering over 6 million calls from farmers in 5 years. |
| 24. | Lifelines India | Internet and telephony-based services, reaching 200,000 farmers (www.lifelines-india.net). |
| 25. | IFFCO Kisan Sanchar Limited (IKSL) | working to advance technology-enabled farms, distribution advisories and building sustainable agriculture practices. Based on Voice messages in local languages, success to reach 10 lakh farmers and 40,000 cooperative societies (www.iksl.in). |
| 26. | Fisher Friend | Mobile-based advisory services for fishing communities of coastal Tamil Nadu, providing information on weather, market prices, etc. |
| 27. | Reuters Market Light (RML) | Micro-information services covering over 440 crops and 1400 markets, providing significant economic benefits to farmers (www.reutersmarketlight.com). |
| 28. | Mobile Advisory Services by Krishi Vigyan Kendras (KVKs) | Provides Mobile advisory services to farmers by KVKs (Farm Science Centres) of ICAR. |
| **Hybrid Projects (Mix of ICTs, Info-mediaries & Conventional Extension Methods)** | | | |
| 29. | e-Arik | Internet based and offline advisory services, showing substantial economic benefits for registered farmers (www.earik.in). |
| 30. | e-Sagu | Agro-advisory services via digital photographs and coordinators, benefiting farmers with increased earnings (www.esagu.in). |
| 31. | Digital Green | Video-based agricultural extension, significantly increasing adoption of farm practices (www.digitalgreen.org). |
| 32. | Knowledge Share Centres | Information provided through touch-screen kiosks, IVRS, bilingual web portal, and awareness campaigns in Andhra Pradesh (www.naipsri.org/ikisan). |

## 6. CONCLUSION

The employment of information and communication technology (ICT) in Indian agriculture has the potential to fundamentally transform the sector through facilitating access to information, boosting productivity, and supporting economic development. Despite the momentum of the advances, it is nevertheless clear that many ICT projects have not made considerable inroads in agricultural information services. This needs to be a more targeted and strategic application of ICT solutions aimed specifically at the needs of farmers and rural areas. India can fully leverage ICT to create a data-driven, efficient, and sustainable agricultural sector that would not only benefit farmers with timely, reliable information but also align with larger agricultural modernisation and economic growth objectives. Additionally, ICT has the potential to drive agricultural sustainability by facilitating practices that conserve inputs, the ecological use of climate resilience, and balance. Enhancing the agenda of sustainability through ICT and sustainable practices will be a major strategy in creating ecological balance, environmental health, and resilience for agricultural systems for the future.

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

We hereby stated that no generative AI tools, including text-to-image generators and large language models (ChatGPT, COPILOT, etc.), were utilized in the preparation or editing of this work.

COMPETING INTERESTS DISCLAIMER:

We declare that none of their known financial, non-financial, or personal relationships might have seemed to have influenced the work described in this publication.

## REFERENCES

Adhya, P. S., & Sahoo, S. K. (2022). Agritech startups in India: A revolutionary idea giving birth to agripreneurs. *International Journal of Innovative Research inn Technology*.

AG Horizon Group Pvt. Ltd. (2023). *Analysis report on sustainable agriculture in India*. AG Horizon Group Pvt. Ltd.

Anajli, Yadav, J., & Priya. (2023). Role of AgriTech startups in India’s agricultural landscape. *International Journal for Research in Applied Science & Engineering Technology (IJRASET)*.

Capozucca, P., Sarni, W., & krause, J. (2012). *Sustainability 2.0-Using sustainability to drive business innovation and growth.* Deloitte Development LLC.

Chowhan, S., & Ghosh, S. R. (2020). Role of ICT on agriculture and its future scope in Bangladesh. *Journal of Scientific Research & Reports*.

Dutta, M., & Anand, K. (2023). Role of information communication technology in agriculture. *International Journal of Novel Research and Development*.

El Bilali, H., & Allahyari, M. S. (2018). Transition towards sustainability in agriculture and food systems: Role of information and communication technologies. *Information Processing in Agriculture, 5*(4), 456–464.

Ernst & Young Report. (2020). *Agritech – Towards transforming Indian agriculture*. Ernst & Young.

Ganeshkuma, C., David, A., & Jebasingh, D. R. (2022). Digital transformation: Artificial intelligence-based product benefits and problems of Agritech industry. *Agri-Food 4.0*. Emerald Publishing Limited.

India Agricultural Outlook Report. (2023). *India Agricultural Outlook Report*. Government of India.

Kshetri, N. (2014). The impacts of cloud computing and big data applications on developing world-based smallholder farmers. In *UBT Knowledge Center* (pp. 103–110). North Carolina, Kosovo.

Lajoie-O'Malley, A., Bronson, K., van der Burg, S., & Klerkx, L. (2020). The future(s) of digital agriculture and sustainable food systems: An analysis of high-level policy documents. *Ecosystem Services, 45*, 101183.

Lin, Y.-P., Petway, J. R., Anthony, J., Mukhtar, H., Liao, S.-W., Chou, C.-F., & Ho, Y.-F. (2017). Blockchain: The evolutionary next step for ICT e-agriculture. *Environments*.

Mohamad, M., & Gombe, I. (2017). e-Agriculture revisited: A systematic Literature Review of Theories, Concept, practices, methods, and future trends. *CORE.*

Mukherjee, S., Padaria, R. N., Burman, R. R., Velayudhan, P. K., Mahra, G. S., Aditya, K., ... & Bhat, A. G. (2025). Global trends in ICT-based extension and advisory services in agriculture: A bibliometric analysis. *Frontiers in Sustainable Food Systems, 9*, 1430336.

National Sample Survey Office. (2022). *NSSO's situation assessment of agricultural households and land and livestock holdings of households in rural India*. Government of India.

Patil, V. C., Gelb, E., Maru, A., Yadaraju, N. T., Moni, M., & Misra, H. (2008). Adoption of information and communication technology (ICT) for agriculture: An Indian case study. In *World Conference on Agricultural Information and IT. IAALD AFITA WCCA*.

Press Information Bureau. (2022, December 16). Use of drones in agriculture sector. Retrieved from Ministry of Agriculture & Farmers Welfare.

Redseer Strategy Consultants. (2023). *India’s AgriTech landscape – A perspective report*. Redseer Strategy Consultants.

Rohila, A. K., Yadav, K., & Ghangh, B. S. (2017). Role of information and communication technology (ICT) in agriculture and extension. *Journal of Applied and Natural Science*.

Saravanan, R. (2012, September). ICTs for agricultural extension in India: Policy implications for developing countries. In *8th Asian Conference for Information Technology in Agriculture, AFITA* (pp. 1–11).

Sharma, N., & Bhambri, P. (2025). The impact of ICT in agriculture and rural development. In *Digital Sustainability* (pp. 227–240). CRC Press.

Shetty, S., & Philip, S. (2022, September). Making agriculture viable for small and marginal farmers. Retrieved from *India Development Review (IDR)*.

Singh, S., Ahlawat, S., & Sanwal, S. (2017). Role of ICT in agriculture: Policy implications. *Oriental Journal of Computer Science and Technology*.

Spanaki, K., Sivarajah, U., Fakhim, M., Despoudi, S., & Irani, Z. (2022). Disruptive technologies in agricultural operations: A systematic review of AI-driven AgriTech research. *Annals of Operations Research*.

The World Bank. (2018). *Investing in Opportunity Ending Poverty.* The world Bank IBRD -IDA.

Torero, M. (2014, October 16). *Food security brings economic growth — not the other way around.* Retrieved from IFPRI: https://www.ifpri.org/