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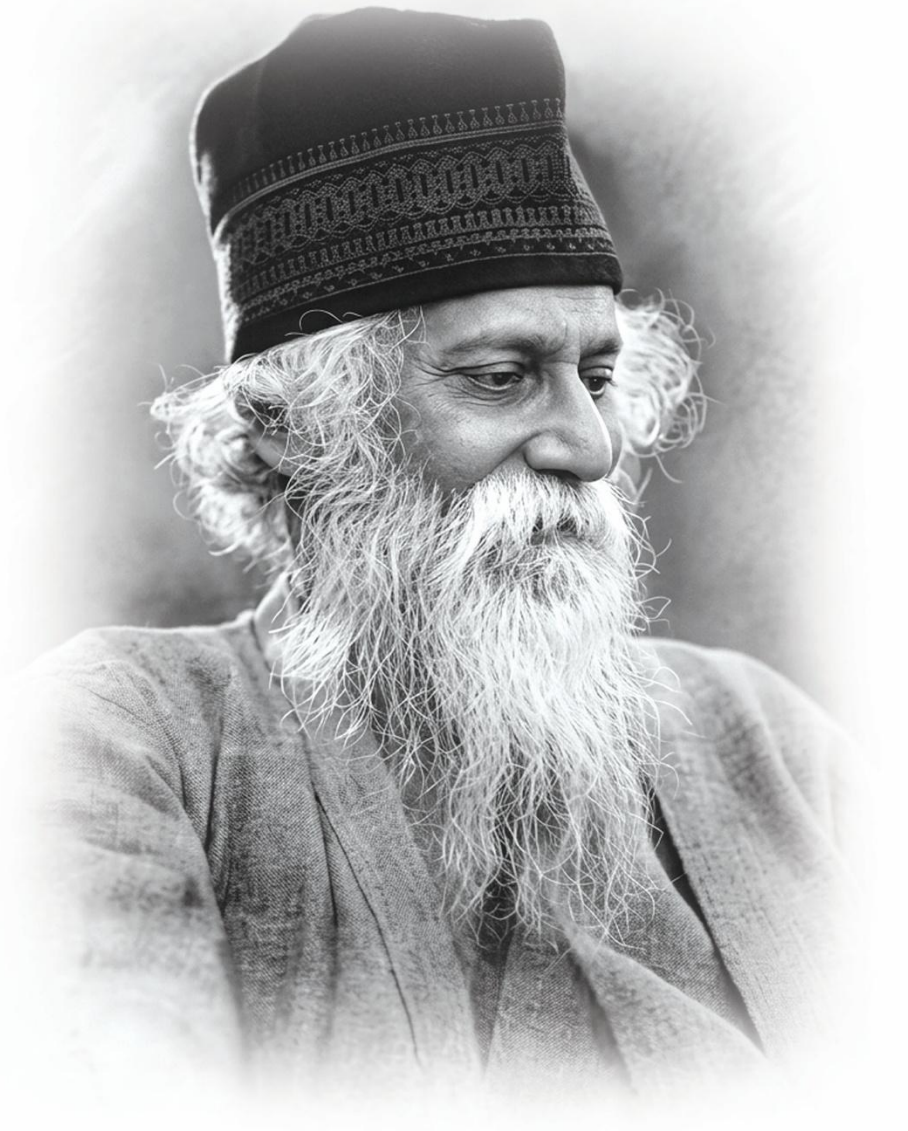
Digital Extension and Its Recent Advancements

Department of Agricultural Extension
Palli Siksha Bhavana (Institute of Agriculture),
VISVA-BHARATI
Sriniketan, West Bengal, 731236

Editorial Board

Where the mind is without fear
and the head is held high
where knowledge is free...



Rabindranath Tagore

Samprasaran
DEPT. OF AGRICULTURAL EXTENSION · VISVA-BHARATI

Digital Extension and Its Recent Advancements

Department of Agricultural Extension
Institute of Agriculture, Palli Siksha Bhavana,
VISVA-BHARATI
Sriniketan, West Bengal, 731236
2026

Foreword

It gives me immense pleasure to present the January–June 2026 issue of *Samprasaran*, the magazine of the Department of Agricultural Extension, Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati. The theme of the present issue, "Digital Extension and Its Recent Advancements," is both timely and significant, particularly as agriculture is witnessing rapid transformation through digital technologies, data-driven approaches, artificial intelligence and smart decision-making.

Agriculture has always been closely associated with knowledge, innovation and the dissemination of scientific information to farming communities. In the present era, digital technologies are creating new avenues for strengthening this process. Mobile communication, social media, the Internet of Things, Geographic Information Systems, remote sensing, drones, decision support systems and artificial intelligence are increasingly contributing to making agricultural information more accessible, timely and responsive to farmers' needs.

The present issue of *Samprasaran* brings together a wide range of perspectives on these emerging developments. The contributions covering digital extension, precision agriculture, IoT, computer-assisted instruction, WhatsApp and YouTube, expert support systems, decision support systems and drone technology provide valuable insights into the changing landscape of agricultural extension. The discussion on emerging national initiatives and digital platforms such as Bharat-VISTAAR, AgriStack and e-NAM further highlights the growing importance of an integrated digital ecosystem for Indian agriculture.

At the same time, technological advancement must remain firmly grounded in the principles of inclusion, accessibility and equity. Digital transformation can achieve its true potential only when its benefits reach small and marginal farmers, rural youth, women and other sections of the farming community. Issues such as the digital divide, digital literacy, access to reliable information and farmers' ability to effectively use digital platforms therefore deserve equal attention. Digital extension should ultimately strengthen the human dimensions of agricultural development by building trust, facilitating participation and addressing local needs.

The scope of this issue extends beyond crop production and encompasses fisheries, dairy, livestock and other emerging dimensions of the agri-food system. The inclusion of themes related to agricultural intelligence, data, carbon, social media influencers and consumer trust reflects the expanding role of digitalization across the agricultural value chain.

The true strength of digital extension lies in its ability to complement human expertise rather than replace it. Technology can enhance the reach and efficiency of extension professionals while enabling farmers to access relevant knowledge, make informed decisions and establish stronger connections with markets, institutions and experts. The ultimate objective must therefore be to use technology as a means for achieving inclusive, sustainable, resilient and farmer-centred agricultural development.

I sincerely appreciate the efforts of the editorial team and all the contributors who have enriched this issue with their valuable ideas and scholarly contributions. I particularly commend Dr. Biswajit Goswami, Associate Professor (Agricultural Extension), for his initiative and dedicated efforts in bringing out the present volume of *Samprasaran.*

I am confident that *Samprasaran* will continue to serve as a meaningful platform for knowledge sharing, academic creativity and constructive dialogue, while contributing to the advancement of agricultural extension education and strengthening its connection with farming communities and society at large.

With my best wishes for the continued success of *Samprasaran.*

Professor (Dr.)Paresh Chandra Kole
Principal, Institute of Agriculture, Palli Siksha Bhavana, Visva-Bharati

Preface

It gives me immense pleasure to present the January–June 2026 issue of *Samprasaran*, the magazine of the Department of Agricultural Extension, Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati. The theme of the present issue, "Digital Extension and Its Recent Advancements," is particularly relevant at a time when agriculture is entering an era increasingly shaped by data, digital connectivity, artificial intelligence and intelligent decision-making.

Agricultural Extension has always been fundamentally concerned with connecting knowledge, technology and people. Digital technologies are now redefining the ways in which this connection can be established, strengthened and scaled. From mobile-based communication and social media to the Internet of Things, Geographic Information Systems, remote sensing, drones, decision support systems and artificial intelligence, the digital transformation of agriculture is opening new possibilities for making extension services more timely, responsive, precise and participatory.

The contributions in this issue offer a valuable panorama of this transformation. They examine the potential of digital technologies to revolutionize agriculture and explore how digital extension can contribute to the transformation of rural India. The discussions on IoT, computer-assisted instruction, WhatsApp and YouTube, precision agriculture, expert support systems, decision support systems and drone technology illustrate the expanding technological repertoire available to extension professionals and farming communities. Equally significant are the emerging national initiatives and digital platforms such as Bharat-VISTAAR, AgriStack and e-NAM, which point towards a more integrated agricultural information and service ecosystem.

What makes this issue particularly meaningful is that it does not view digitalization merely as a technological phenomenon. The articles addressing farmer adoption, digital inclusion, the digital divide and the challenges faced by smallholder farmers remind us that access to technology does not automatically translate into access to knowledge, opportunity or empowerment. The ultimate measure of digital extension must therefore be its ability to reach the last mile, build trust, respond to local needs and ensure that no farming community is left behind.

The scope of the issue also extends beyond crop production to fisheries, dairy and livestock, while examining emerging dimensions such as data, carbon and agricultural intelligence. The inclusion of perspectives on social media influencers and consumer trust further demonstrates how digitalization is reshaping not only the production side of agriculture but the entire agri-food ecosystem.

The real promise of digital extension lies not in replacing the human element of extension, but in augmenting the capacity of extension professionals and empowering farmers with better information, better choices and better connections. Technology must remain a means to achieve inclusive, sustainable and farmer-centred development.

I congratulate the editorial team and all the contributors for their sincere efforts in bringing out this issue. The effort of Dr. Biswajit Goswami, Associate Professor (Agricultural Extension) to bring out the present volume deserves all appreciation. I hope that *Samprasaran* will continue to flourish as a forum for knowledge sharing, creativity and constructive dialogue, while strengthening the spirit of extension education and its commitment to society.

With my best wishes

Professor (Dr.)Souvik Ghosh
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Executive Summary

The January–June 2026 issue of Samprasaran, published by the Department of Agricultural Extension, Palli Siksha Bhavana, Visva-Bharati, focuses on the theme "Digital Extension and Its Recent Advancements." The issue looks at how digital technologies are changing agricultural extension and creating new ways of connecting farmers with information, experts, markets and services. It brings together views on emerging technologies as well as the opportunities and challenges associated with their use in agriculture.

Agricultural extension has always been about connecting knowledge with farmers. Traditionally, this has been done through personal visits, demonstrations, training programmes, meetings and other face-to-face activities. These methods remain important because farmers value personal interaction, practical experience and trust. However, agriculture is changing rapidly. Farmers need timely information about weather, crops, pests, diseases, markets and new technologies. Digital extension can support the existing system by making useful information available faster and reaching more farmers.

The articles in this issue present a wide range of digital tools that are becoming important in agriculture. These include mobile phones, WhatsApp, YouTube, Artificial Intelligence (AI), the Internet of Things (IoT), Geographic Information Systems (GIS), remote sensing, drones, Computer-Assisted Instruction and Decision Support Systems (DSS). These technologies can help farmers and extension professionals access and share information more quickly. They can also support better farm decisions by bringing together information from different sources.

One important lesson from the issue is that digital extension is not simply about technology. The real purpose is to make agricultural knowledge useful and practical for farmers. For example, AI and expert systems can help provide solutions to farm problems, while IoT devices can collect information on soil and environmental conditions. Drones and remote sensing can help monitor crops and identify problems at an early stage. Decision Support Systems can assist farmers by combining information on weather, soil, crops and markets. In this way, digital technologies can make extension services more timely and better suited to farmers' needs.

The issue also discusses the growing role of WhatsApp, YouTube and digital learning in agricultural extension. Farmers can use these platforms to watch demonstrations, share their experiences, ask questions and learn from other farmers. Digital learning can also support students, extension workers and rural communities. However, digital platforms may also spread incorrect or misleading information. Therefore, reliable sources, expert guidance and proper verification of information are very important.

Another important area covered in the issue is the development of digital agricultural platforms and public infrastructure. Initiatives such as Bharat-VISTAAR, AgriStack and e-NAM show how digital systems are being used to improve agricultural services and market access. Such initiatives can help connect information, advisory services, farmers and markets in a more organised manner. The growing use of AI and agricultural data also opens new possibilities for providing more personalised and timely advice to farmers.

The importance of digital extension is not limited to crop farming. The issue also considers fisheries, dairy and livestock, which are important parts of rural livelihoods. Digital tools can provide information on production practices, disease management, weather, markets and other farm-related decisions. For fish farmers and livestock owners, timely information can be particularly useful. However, digital services work best when

they are supported by extension professionals who understand local conditions and can help farmers apply the information in practice.

A major concern discussed in the issue is the digital divide. Not every farmer has the same access to smartphones, internet services, digital platforms or technical knowledge. Small and marginal farmers, women, elderly farmers and people living in areas with poor connectivity may face greater difficulties. Cost, language, digital literacy and lack of confidence can also affect the use of digital services.

The issue also shows that digitalisation is changing the wider agricultural value chain. It is influencing not only production but also marketing, consumer behaviour, data use and agricultural decision-making. Platforms such as e-NAM can improve farmers' access to market information and provide greater choice. At the same time, the growing importance of agricultural data and intelligence is creating new opportunities for planning and decision-making.

Overall, the issue makes it clear that the future of agricultural extension should not be seen as a choice between technology and people. Both are important. Digital technology can provide speed, wider reach and timely information, while extension professionals bring experience, understanding, trust and personal support. Farmers should also be active participants rather than passive users of digital services.

The central message of Samprasaran is therefore simple: digital technology should bring agricultural knowledge closer to farmers and help them make better decisions. Technology should support people, not replace the human side of extension. The future of digital extension will depend on reliable information, inclusive connectivity, local-language communication, digital literacy, responsible use of data and continued interaction between farmers and extension professionals.

In this way, digital extension can become a powerful support system for farmer-centred, inclusive, sustainable and resilient agriculture. Its greatest success will come not from the most sophisticated technology, but from technology that reaches ordinary farmers, responds to their real problems and helps improve their livelihoods.

Contents

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Can Digital Technologies Revolutionize the Future of Agriculture?

Madhusmita Sahoo[1] and Souvik Ghosh[2]

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"The future of agriculture lies not only in fertile soil but also in the intelligent use of digital innovation."

Agriculture has always been the backbone of human civilization, yet farmers often face challenges in accessing timely and reliable information. Today, digital technologies are transforming agricultural extension education by connecting farmers with knowledge, experts, and markets like never before. From smartphones to artificial intelligence (AI), digital innovation is reshaping the way agricultural information is shared and utilized.

Traditionally, farmers depended on face-to-face interactions with extension workers to obtain guidance on crop production, pest management, and farm practices. However, limited manpower, inadequate resources, and geographical barriers often restricted the reach of such services. Digital technologies have emerged as powerful solutions to bridge this gap.

Mobile-based platforms have become one of the most effective tools for agricultural knowledge dissemination. Mobile applications, SMS advisory services, and interactive voice systems provide farmers with instant access to weather forecasts, market prices, crop management practices, and pest-control recommendations. These tools enable farmers to make informed decisions at the right time, leading to improved productivity and profitability.

Artificial Intelligence (AI) is revolutionizing farming practices. AI-powered advisory systems analyze weather conditions, soil characteristics, and crop health data to generate personalized recommendations. Farmers can now receive real-time guidance on irrigation, fertilizer application, and disease management. Similarly, AI-driven chatbots provide quick responses to farming queries, making expert advice accessible around the clock.

The Internet of Things (IoT) has introduced a new era of precision agriculture. Smart sensors installed in fields monitor soil moisture, temperature, and humidity, enabling farmers to optimize resource use. Drones and satellite technologies help detect crop stress, pest infestations, and nutrient deficiencies at an early stage, reducing losses and increasing efficiency.

Another promising innovation is blockchain technology, which enhances transparency and traceability across agricultural supply chains. Digital record-keeping systems ensure secure data management, helping farmers, traders, and consumers build trust in agricultural products.

Digital media platforms such as YouTube, webinars, podcasts, social media groups, radio, and television programs are also playing a significant role in spreading agricultural knowledge. These platforms encourage farmer-to-farmer learning, collaboration, and the exchange of successful farming experiences.

Despite these remarkable advancements, challenges remain. Limited internet access, high technology costs, low digital literacy, language barriers, and infrastructure gaps continue to hinder widespread adoption, particularly in rural communities. Addressing these issues requires affordable technologies, inclusive digital literacy programs, supportive government policies, and strong public-private partnerships.

As the world moves towards smart agriculture, integrating AI, IoT, blockchain, and mobile technologies will create more efficient, sustainable, and resilient farming systems. Digital innovation is no longer a luxury; it is becoming a necessity for ensuring food security and empowering farmers in the twenty-first century.

Transforming Rural India Through Digital Extension

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Almost half of India's workforce is employed in agriculture, which continues to be the foundation of the country's rural economy. However, traditional farming suffers structural issues like dispersed landholdings, unpredictability in the environment, and restricted market access, which lead to low productivity and erratic earnings. For rural India, digital extension — the application of information and communication technologies (ICTs) to provide agricultural knowledge and services — has become revolutionary. With about 548 million rural internet users (57% of India's total) expanding four times faster than urban regions, the way extension services are provided to farmers is about to undergo a significant change.

Agritech as a Driver of Rural Transformation

Technology integration in agriculture has been made possible by the quick growth of digital platforms, mobile access, and internet connectivity. To increase productivity and decision-making, agritech uses digital marketplaces, drones, remote sensing, IoT, and artificial intelligence (AI).

These developments enable:

- Data-driven, real-time farming decisions based on crop health, soil, and weather
- Better pricing discovery and market connections
- Improved credit, input, and advisory service accessibility

With the potential to raise farmer incomes by 25–35% and support the SDGs (Zero Hunger, No Poverty), agritech firms and digital platforms are closing gaps between farmers, markets, financial institutions, and information networks.

Key Technologies and Their Impact

In India, digital infrastructure, mostly via BharatNet and Common Service Centres, makes it easier for rural farmers to access e-governance and agricultural recommendations. Crop advisories and real-time data interchange are improved by the introduction of 5G and AI platforms such as Kisan e-Mitra, which has been adopted by 44% of rural users. Programs like AgriStack and the Digital Agriculture Mission make it easier for farmers to get subsidies and individualised services, which could boost their earnings by 25% to 35%. Drones and Internet of Things sensors are examples of technologies that increase precision farming, leading to lower input costs and higher productivity. While digital governance tools enable village-level participatory governance, the JAM Trinity enhances welfare delivery by facilitating direct benefit transfers.

Challenges and the Road Ahead

Digital literacy gaps, connectivity issues in distant and tribal areas, high technological prices for small farmers, and data privacy concerns remain enduring issues despite tremendous advances. The path ahead requires:

- Providing underprivileged villages with more accessible broadband and 5G infrastructure
- Developing regional language interfaces and capacity-building initiatives to improve digital literacy
- Encouraging the adoption of technology by farmer-producer organisations (FPOs)
- Creating strong data governance frameworks to safeguard the interests of farmers
- Promoting collaborations between the public and private sectors in agritech

Conclusion

Digital extension is now the main driver of agricultural outreach rather than just a supplement. Technology is changing the way rural India lives, learns, and makes money. Examples include AI advisory, drone-based services, digital credit, and smart government. Realising the vision of a resilient, wealthy, and Viksit Bharat @2047 will require consistent investment in digital literacy, infrastructure, and inclusive policy design.

Internet of Things (IoT): A New Era of Digital Extension in Agriculture

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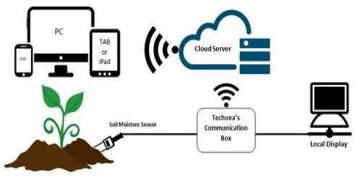
Agricultural extension has long served as the bridge between research institutions and farmers by disseminating improved technologies and farming practices. Today, rapid advancements in information and communication technologies have transformed this process into a digital extension, enabling faster, more accurate, and need-based advisory services. Among these advancements, the Internet of Things (IoT) has emerged as one of the most significant innovations, bringing intelligence and automation to agriculture. IoT refers to a network of interconnected devices equipped with sensors, software, and internet connectivity that collect, transmit, and analyse real-time data. In agriculture, these smart devices continuously monitor field conditions, enabling farmers and extension personnel to make timely, informed decisions. Instead of relying solely on periodic field visits, extension professionals can now provide location-specific recommendations based on live information from farms, making advisory services more efficient and responsive.




IoT has found diverse applications across modern agriculture. Soil moisture sensors help determine the optimum time for irrigation, reducing water wastage and improving water-use efficiency. Weather stations provide real-time information on temperature, humidity, rainfall, and wind conditions, enabling farmers to prepare for adverse weather events. Sensors also monitor soil nutrients and crop health, allowing precise application of fertilizers and pesticides while minimizing production costs and environmental pollution. IoT has further strengthened precision agriculture through integration with drones, GPS, satellite imagery, and cloud computing, helping farmers detect pest and disease outbreaks, monitor crop growth, and assess field variability with greater accuracy.

In livestock farming, wearable sensors monitor animal health, feeding behaviour, body temperature, and movement, facilitating early disease detection and improving productivity. Similarly, IoT-enabled greenhouse automation regulates temperature, humidity, irrigation, and lighting, ensuring

optimal growing conditions with minimal human intervention. These technologies not only enhance farm productivity but also provide extension personnel with real-time field information, enabling evidence-based recommendations tailored to farmers' needs.

Despite its immense potential, the adoption of IoT in Indian agriculture faces several challenges, including high initial investment, inadequate internet connectivity in rural areas, fragmented landholdings, and limited digital literacy among farmers. Strengthening rural digital infrastructure, promoting affordable smart devices, and organizing capacity-building programmes for farmers and extension personnel are essential to overcome these barriers. In addition, greater collaboration among research institutions, agricultural universities, Krishi Vigyan Kendras (KVKs), start-ups, private technology companies, and government agencies can accelerate the development and adoption of IoT-based solutions. Such partnerships can facilitate field demonstrations, farmer training, and localized digital advisory services, ensuring that even small and marginal farmers benefit from these emerging technologies.

As agriculture moves towards greater precision, sustainability, and climate resilience, IoT will continue to redefine the way extension services are delivered. By integrating real-time data with scientific knowledge, IoT empowers farmers to make informed decisions, optimize resource use, increase productivity, and reduce production risks. Thus, IoT is not merely a technological advancement but a transformative force driving the future of digital extension and sustainable agricultural development.

Computer Assisted Instruction: The Backbone of Digital Learning in Extension Services

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In today's rapidly evolving agricultural landscape, digital extension has emerged as a transformative force, revolutionizing how knowledge is shared and applied. At the heart of this revolution lies Computer Assisted Instruction (CAI) — a pioneering approach that blended technology with teaching to empower learners and practitioners in agriculture. From its early roots to modern applications, CAI has transformed education by making learning interactive, accessible, and deeply connected to real-world agricultural practices.

Computer Assisted Instruction (CAI) is an interactive instructional technique whereby a computer is used to present the instructional material and monitor the learning that takes place. It is a self-learning technique, usually offline/online, involving interaction of the user with programmed instructional materials. There are various terminologies related to this, viz., Computer-Based Instruction (CBI), Web Based Instruction (WBI), Computer Assisted Learning (CAL), Computer Enriched Instruction (CEI) and Web Based Training (WBT).

The origin of CAI dates back to Sydney Pressey's multiple-choice machine (1925), which allowed learners to test themselves interactively. Later, the PLATO (Programmed Logic for Automatic Teaching Operations) system in the 1960s and Patrick Suppes' computerized tutorials in arithmetic and reading marked milestones in making CAI a mainstream educational tool. These early experiments paved the way for today's sophisticated digital learning platforms.

Computer-Assisted Instruction (CAI) operates through a straightforward yet effective cycle. The system poses a question or prompt, the learner responds, and the computer immediately evaluates that response, offering either positive reinforcement or corrective feedback. This continuous loop promotes self-paced study, keeps learners actively engaged, and accelerates knowledge acquisition.

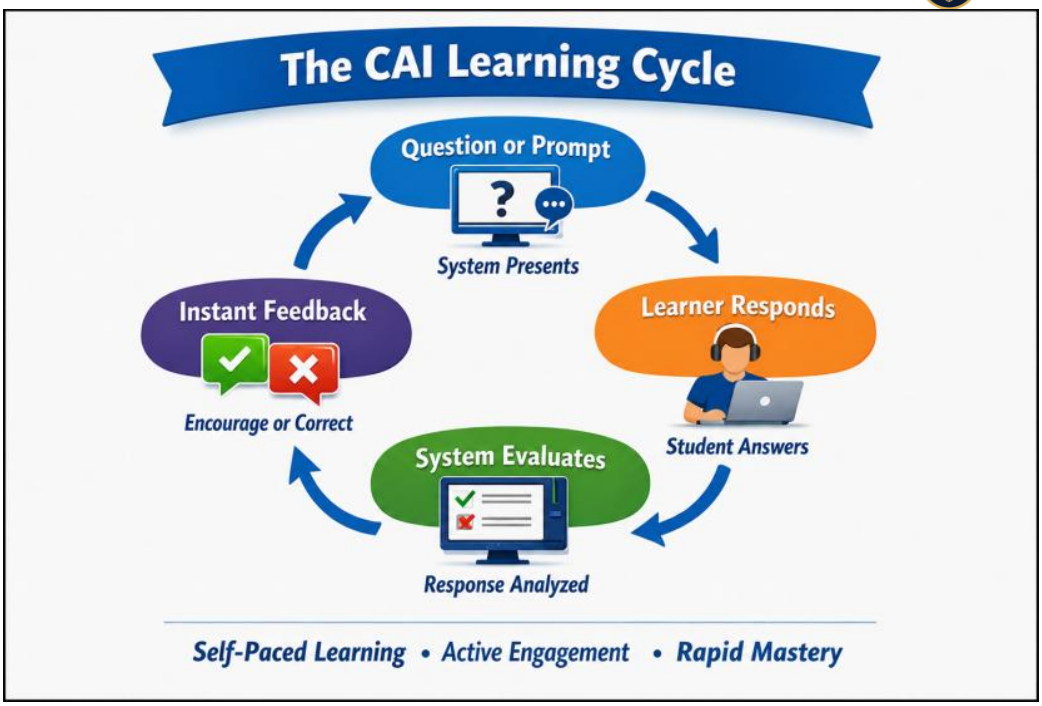

Fig. 1: Computer-Assisted Instruction learning cycle

CAI offers a flexible range of delivery methods that makes it ideal for extension services, offering multiple instructional modes:

- Drill and Practice — reinforcing skills through repetition, such as soil testing or disease identification.
- Games — turning lessons into contests that motivate learners.
- Simulation — safe, risk-free environments for training in pest management or climate adaptation.
- Discovery — encouraging exploration of agricultural databases.
- Problem Solving — teaching strategies through real-world scenarios like irrigation planning.
- Tutorials — combining information delivery with interactive practice.

In extension services, CAI plays a vital role by supporting weather forecasting for crop planning, production estimation for policy and market guidance, digital record keeping, community knowledge sharing, and time-saving technologies that boost efficiency and productivity. Altogether, these applications demonstrate CAI's power to bridge information gaps and deliver timely, actionable insights to farmers and learners alike.

Computer-Assisted Instruction (CAI) offers significant advantages in digital extension by enabling personalized one-to-one interaction, instant feedback, learner privacy, self-directed study, and multi-sensory methods that make complex topics easier to grasp, often resulting in faster learning than traditional approaches. At the same time, it faces challenges such as equipment breakdowns that disrupt lessons, excessive multimedia that can overwhelm learners, a tendency toward mechanical

rather than human-centered learning, and infrastructure limitations in rural areas that restrict access. To fully realize CAI's potential, these barriers must be addressed so its benefits can be scaled effectively across extension services.

The future of CAI in digital extension is being transformed by modern technologies that make learning more personalized, interactive, and accessible. With AI-driven personalization, gamification, immersive VR/AR training, big data insights, mobile-first lessons, and collaborative platforms, CAI is evolving into a farmer-centered tool that keeps extension services relevant in a fast-changing world. More than just a teaching method, CAI is becoming the backbone of digital learning, ensuring knowledge flows seamlessly from experts to communities and empowering farmers to adapt quickly, boost productivity, and thrive in a knowledge-driven agricultural economy.

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Role of WhatsApp and YouTube in Farmer-to-Farmer Knowledge Sharing

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Abstract: *WhatsApp and YouTube have emerged as effective digital platforms for agricultural extension by facilitating farmer-to-farmer knowledge sharing and improving access to timely agricultural information. Their widespread adoption enhances peer learning, technology dissemination, and decision-making. Despite challenges such as misinformation and the digital divide, these platforms significantly strengthen extension services and support sustainable agricultural development.*

Keywords: *WhatsApp, YouTube, digital platforms, decision-making*

Introduction

Digital technologies have transformed agricultural extension by enabling faster and more accessible exchange of information among farmers. India had about 958 million active internet users in 2025, with 57% living in rural areas. Indians spend an average of about 3.2 hours per day on social media. India had 1.12 billion mobile connections in early 2025 (76.6% of the population). With the increasing availability of smartphones and internet connectivity, social media platforms have become valuable tools for sharing agricultural knowledge (Thakur & Chander, 2018). Among these platforms, WhatsApp and YouTube are widely used because they are simple, affordable, and support communication in local languages (Singh et al., 2021). These digital platforms promote farmer-to-farmer knowledge sharing by allowing farmers to exchange experiences, learn improved farming practices, and access timely information (Nain et al., 2019). As a result, they complement conventional extension services and contribute to informed decision-making in agriculture (Coggins et al., 2025).

WhatsApp as a Knowledge-Sharing Tool

WhatsApp has become one of the most popular communication platforms among farmers (Nain et al., 2019). WhatsApp has over 500 million users in India, making India its largest market. Through farmer groups, cooperatives, and extension networks, users can instantly share text messages, photographs, videos, voice notes, and documents related to agriculture (Coggins et al., 2025). Farmers frequently discuss crop management practices, pest and disease outbreaks, fertilizer recommendations, irrigation techniques, and market prices (Nain et al., 2019; Thakur & Chander, 2018; Patel et al., 2020). The platform also enables experienced farmers to guide others by sharing practical solutions based on their own field experiences (Sah et al., 2021). Agricultural experts and extension personnel can participate in these groups to provide timely advice, making information exchange faster and more interactive (Agha et al., 2018). Its low cost, ease of use, and real-time communication make WhatsApp an effective medium for peer learning.

YouTube as a Learning Platform

YouTube's advertising reach in India was about 491 million users in early 2025, increasing to around 500 million by late 2025. YouTube has emerged as an important educational platform for farmers because it provides visual demonstrations of agricultural technologies and practices (Tambade et al., 2021). Farmers can watch videos on improved crop cultivation, integrated pest management, organic farming, livestock management, farm mechanization, and post-harvest handling. Demonstration videos help users understand complex techniques more effectively than written instructions (Satyapriya et al., 2017). Many agricultural universities, research organizations, extension agencies, and progressive farmers upload educational content in regional languages, making it accessible to a wider audience. Farmers can view videos repeatedly at their convenience, allowing them to learn at their own pace and apply new practices confidently in their fields. Popular Bengali agricultural YouTube channels such as Banglar Krishi, Agriculture Helper Bengali, Krishi Banglar Krishi TV, Modern Krishi and World Smart Farmer play an important role in disseminating practical farming knowledge by sharing information on crop production, pest and disease management, modern farming techniques, and farmer success stories, thereby supporting farmer-to-farmer knowledge exchange and digital agricultural extension.

Benefits and Challenges

The use of WhatsApp and YouTube offers several advantages for agricultural knowledge sharing. These platforms enable rapid dissemination of information, encourage peer-to-peer learning, reduce the cost of extension services, and improve farmers' access to expert advice. They also promote innovation by exposing farmers to successful practices adopted in different regions. However, certain challenges limit their effectiveness. Misinformation and unverified agricultural advice can mislead farmers and result in poor decision-making (Chowdhury et al., 2024). Limited internet connectivity, low digital literacy, language barriers, and unequal access to smartphones also restrict the use of these platforms, particularly in remote rural areas. Therefore, ensuring the credibility of digital content and improving farmers' digital skills are essential for maximizing their benefits.

Conclusion

WhatsApp and YouTube have significantly strengthened farmer-to-farmer knowledge sharing by making agricultural information more accessible, interactive, and timely. These platforms complement traditional extension systems by connecting farmers with experts and fellow practitioners while encouraging continuous learning (Singh et al., 2019). Although challenges such as misinformation and the digital divide remain, appropriate digital literacy programmes, reliable content creation, and institutional support can enhance their effectiveness. As digital agriculture continues to evolve, WhatsApp and YouTube will play an increasingly important role in promoting sustainable agricultural development, improving technology adoption, and empowering farming communities.

Digital Influence and Consumer Trust: The Impact of Social Media Influencers on Generation Z Consumers

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The rapid advancement of digital technology has transformed modern marketing practices and changed the way consumers interact with brands. Among the most influential developments is the rise of social media influencers, who have become powerful communicators in the digital marketplace. For Generation Z, a group that has grown up with social networking platforms and online media, influencers play a major role in shaping opinions, preferences, and purchasing decisions. Platforms such as Instagram, YouTube, Facebook, and TikTok have created opportunities for influencers to connect directly with audiences and influence their consumption patterns.

This discussion focuses on the influence of social media personalities on the buying behavior of Gen Z consumers, particularly through factors such as trust, authenticity, engagement, and content relevance. Unlike traditional advertisements, influencer marketing creates a more personal form of communication. Influencers often share lifestyle experiences, product reviews, and daily activities, allowing followers to feel emotionally connected to them. This sense of connection increases the likelihood that followers will value and trust the recommendations provided by influencers.

Online engagement indicators, including likes, comments, shares, and views, also contribute significantly to consumer perception. These engagement metrics act as signs of popularity and acceptance, encouraging users to believe that a product or service is reliable and widely appreciated. Young consumers, especially Gen Z, are highly influenced by such digital interactions because they often view online approval as a measure of credibility. Nevertheless, audience engagement alone does not guarantee persuasive impact. In recent years, consumers have become more conscious of paid collaborations and promotional content, making honesty and transparency essential for influencer effectiveness.

The relationship between influencers and consumer behavior can be understood through established communication and psychological theories. Source Credibility Theory suggests that people are more persuaded by individuals they perceive as dependable, attractive, and knowledgeable. Likewise, the Elaboration Likelihood Model explains that consumers may either carefully analyze promotional messages or rely on simple cues such as popularity, appearance, or follower count. When influencers are seen as genuine and trustworthy, consumers are more likely to process information positively and develop favorable attitudes toward promoted brands.

In India, the influencer marketing industry has expanded rapidly due to increased internet accessibility, smartphone usage, and social media engagement among youth. Businesses are actively collaborating with influencers to reach younger audiences in a cost-efficient and relatable manner. Sectors such as fashion, beauty, travel, gaming, and technology are particularly benefiting from this trend. However, the increasing use of influencer promotions has also raised concerns regarding deceptive advertising practices and undisclosed sponsorships, emphasizing the importance of ethical marketing practices.

In conclusion, social media influencers have emerged as important drivers of consumer behavior among Generation Z. Their ability to build trust, maintain authenticity, and generate engagement allows them to shape purchasing intentions effectively in the digital environment. For brands and marketers, successful influencer marketing depends not only on visibility and popularity but also on establishing genuine relationships with audiences. As digital platforms continue to grow, influencer marketing is expected to remain a major force in modern advertising and consumer communication.

Digital Extension: Bridging the Last Mile Between Knowledge and the Field

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Agriculture, the oldest conversation between humanity and the earth, has always depended on the timely flow of knowledge. For decades, that flow moved slowly, carried through field visits, printed pamphlets, and seasonal training camps held under the open sky. The extension worker, cycling through muddy village lanes with a folder of recommendations, was the primary vessel of agricultural knowledge. Today, digital extension has rewritten the grammar of that conversation. It is not merely a tool adopted by institutions; it represents a transformation in how knowledge is created, carried, and received by farming communities, including the quiet mechanics by which raw data eventually becomes a farmer's decision.

The Shift from Push to Pull

Traditional extension operated on a push model in which experts delivered standardised information to largely passive recipients, often irrespective of the farmer's immediate need. Digital extension has inverted this relationship. Through interactive voice response systems, WhatsApp-based advisory groups, and mobile applications such as Kisan Suvidha and mKisan, farmers now pull the knowledge they need, precisely when they need it. This on-demand character is arguably the most consequential advancement of digital extension, aligning information delivery with real-time field decisions rather than administrative schedules set far from the ground reality.

Emerging Technologies Reshaping Extension

Three technologies are redefining the frontier of extension science. Artificial Intelligence enables hyper-localised crop advisory systems that analyse soil, weather, and pest data to generate customised recommendations, moving extension from generalised guidance to precision counsel. Drones, once confined to research stations, now serve as active extension instruments for real-time crop stress scouting and targeted input application. Satellite remote sensing integrated with Geographic Information Systems has further empowered departments to monitor crop conditions at scale and allocate resources with unprecedented precision.

From Raw Data to a Farmer's Decision: The Conversion Pipeline

Behind every digital advisory lies a quieter process: the conversion of raw, technical data into a unit of information a farmer can act upon. A decade ago, this conversion happened almost entirely by human hand, a specialist reading a soil report or weather bulletin and translating it through personal judgement, slow and difficult to scale beyond a handful of villages at a time.

That practice has shifted substantially with AI-based conversion tools. Sensor readings, satellite imagery, and weather records are now fed into machine learning models that perform much of this

translation automatically. A soil moisture value, for instance, is converted into a simple, colour-coded irrigation cue; a spectral index becomes a one-line pest alert in the farmer's own dialect. What once required an officer interpreting a paper report now happens through data ingestion, model inference, and message simplification, often within minutes.

This evolution has unfolded in phases: early tools simply digitised printed bulletins into SMS text; rule-based systems then introduced fixed thresholds for standard alerts, faster but still rigid; and the current machine-learning phase allows the conversion unit itself to learn from farmer feedback, refining advisory timing over successive seasons, making conversion an evolving process rather than a one-time translation.

Theoretical and Conceptual Support

This diffusion aligns with Rogers' Diffusion of Innovation Theory (1962), which explains how new ideas spread within a social system, with progressive farmers adopting digital tools first and the wider community following in the familiar S-curve. The Elaboration Likelihood Model (Petty and Cacioppo, 1986) further explains why simplicity in AI-converted messages matters: content processed for cognitive ease is more likely to be acted upon, a principle central to designing effective advisories for diverse agro-climatic zones (Meera et al., 2004).

Challenges and Issues

Optimism must be grounded in an honest assessment of limitations. Digital extension cannot reach those who lack devices, connectivity, or digital literacy, often the very farmers most in need of support. Automated conversion units, however efficient, can misread local nuance when trained on data from a different agro-climatic context, producing advisories that are accurate yet practically misleading. Departments must invest in digital literacy, vernacular content design, and human oversight of AI-generated advisories, alongside addressing data privacy and platform dependency concerns (Mittal and Mehar, 2016).

Conclusion

The future of digital extension lies not in replacing the extension worker but in augmenting capacity through increasingly intelligent conversion of data into usable knowledge. When a field officer carries diagnostics already translated into plain language, human empathy and computational precision function as a single system. Digital extension, at its most meaningful, is about shrinking the distance between what science measures and what a farmer can confidently act upon, a distance that narrows further with every improvement in how raw information becomes human understanding (Saravanan, 2010).

Precision Agriculture in India: Leveraging DSS, GIS, and Remote Sensing for Sustainable Farming

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Indian agriculture, which employs nearly 58% of the rural population and contributes about 17% to national GDP, is under increasing pressure from climate variability, resource depletion and food insecurity. The country has over 120 million farm holdings, many of them fragmented and rain-fed, and is in need of technology-driven solutions that can be scaled up at the earliest. The synergistic integration of Decision Support Systems (DSS), Geographic Information Systems (GIS) and Remote Sensing (RS) in this context provides a compelling framework for smarter and data-driven agricultural governance. High resolution multi-temporal imagery from remote sensing platforms such as ISRO's Resourcesat, Cartosat and global sensors like Sentinel and Landsat is used for real-time monitoring of crops, soil health assessment and drought mapping. GIS provides spatial organization to this data and DSS converts it into actionable insights for farmers, policymakers and extension workers. The institutional relevance of these tools in the agricultural planning machinery in India is already evident from established programmes like NADAMS, Fasal project and Crop Acreage and Production Estimation (CAPE).

Upside potential is enormous. The integration of DSS, GIS and RS, which is the driving force of precision agriculture, can optimize the scheduling of irrigation, application of fertilizers and control of pests, leading to a direct reduction in the cost of inputs and environmental degradation. Vegetation indices based on satellite data such as NDVI allow for good yield forecasting, which contributes to price stability and planning of procurement. Drone-based imagery, together with AI-enabled DSS platforms, has the potential to improve the spatial granularity of field-level interventions further. Disastrous losses can be avoided by smallholder farmers if flood and drought early warning systems are put in place. India's rapidly increasing smartphone penetration and rural digital infrastructure also offer fertile ground for mobile-based DSS applications providing localized, vernacular crop advisories to cultivators.

Widespread adoption faces big obstacles. The average farm size in India is less than 1.1 ha and thus needs a spatial resolution at sub-field level, better than what is usually available from satellite data. Government databases and remote sensing platforms are fragmented, have poor interoperability and create data silos; high infrastructure costs, lack of skilled technical personnel at district levels, poor rural internet connectivity and low digital literacy among farmers remain key structural challenges. Inconsistent ground truth validation further decreases reliability of satellite-based recommendations.

A comprehensive multi-pronged strategy is essential: develop and scale out affordable, multilingual DSS mobile tools suited to local agroclimatic zones; develop collaborative frameworks between ISRO, ICAR and state agricultural universities to accelerate research to field translation; expedite BharatNet infrastructure expansion to address rural connectivity gaps; and build the capacity of Krishi Vigyan Kendras (KVKs) and extension officers to ensure effective last-mile delivery. DSS, GIS and Remote Sensing together can be a game changer for Indian agriculture. This powerful triad of sustained policy investment, institutional collaboration and farmer-centric technology design can propel productivity, climate resilience and rural prosperity, and steer India towards enduring food and agricultural security.

Bharat-VISTAAR: Sowing the Future of Indian Agriculture

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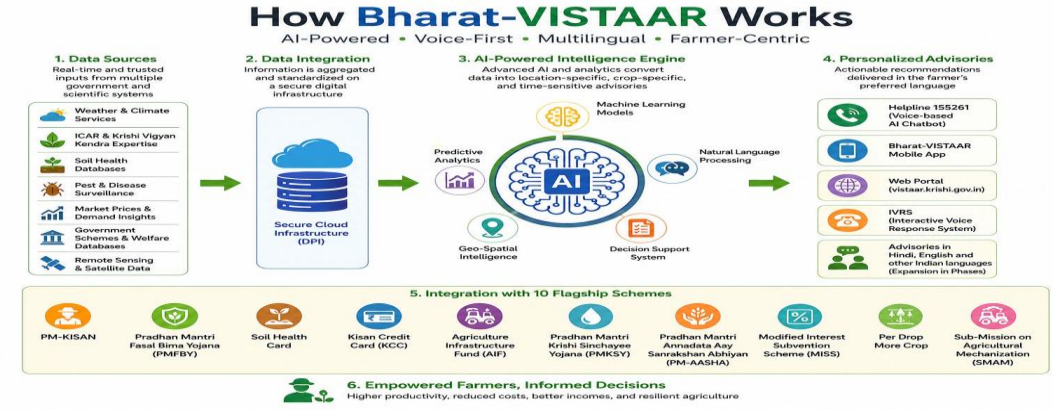
"If agriculture goes wrong, nothing else will have a chance to go right."
— Dr. M. S. Swaminathan

Few lines explain the development journey of India as much as these words of Dr. M. S. Swaminathan. Agriculture has always been the basis of the country's food security, rural livelihoods and economic resilience. More than five decades after the Green Revolution transformed India's food security, the country is preparing for another revolution, and it's not driven by high-yielding varieties or irrigation, but by Artificial Intelligence (AI) and Digital Public Infrastructure (DPI). Bharat-VISTAAR represents this new chapter, where data, science, and technology converge to empower every farmer with timely and personalized agricultural intelligence.

Agriculture remains the backbone of India's economy, yet timely access to reliable information has long been a challenge for millions of farmers. Weather uncertainties, pest outbreaks, fluctuating market prices, and fragmented access to government schemes often affect farm decisions. To fill this gap, the Indian Government launched Bharat-VISTAAR (Virtually Integrated System to Access Agricultural Resources), an AI-enabled, voice-first, multilingual DPI announced in the Union Budget 2026–27 with an allocation of ₹150 crore. It is being created as a single digital ecosystem for real-time, location-specific and personalized advisories to farmers and seamless access to allied agricultural services.

Launched on 17 February 2026, Phase I is available in Hindi and English through a dedicated helpline (155261), a voice-activated AI chatbot, the Ministry's website and a mobile application. Bharat-VISTAAR recognizes that digital inclusion does not mean only smartphone users, and provides Interactive Voice Response System (IVRS) access to small and marginal farmers for accessing scientific advisories on basic mobile phones. The Government plans to introduce nine more Indian languages in a phased manner on the platform to make it more accessible across the country.



Bharat-VISTAAR is not a separate portal but an integration of trusted information from government digital ecosystems and scientific institutions such as ICAR, weather services, market intelligence, soil health databases, pest and disease surveillance systems and government programmes. Artificial Intelligence then analyses these datasets and offers farmers customized recommendations for crop management, irrigation, nutrient application, pest control, harvesting, and market opportunities. The platform converts dispersed data into useful knowledge, enabling farmers to make the right decisions at every stage of cultivation. The platform also integrates ten flagship Central Government schemes, including PM-KISAN, PMFBY, Soil Health Card, Kisan Credit Card, Agriculture Infrastructure Fund, PM Krishi Sinchayee Yojana, PM-AASHA, the Modified Interest Subvention Scheme, Per Drop More Crop, and the Sub-Mission on Agricultural Mechanization. Instead of navigating multiple offices and portals, farmers can access services through a single digital interface, making agricultural governance simpler, faster, and more farmer-centric. Bharat-VISTAAR has been developed in compliance with the Digital Personal Data Protection Act, 2023 and cybersecurity guidelines defined by MeitY and CERT-In, ensuring that farmers' data will be handled in a secure manner through periodic security audits and continuous risk assessment.

As India marches towards Viksit Bharat 2047, Bharat-VISTAAR is much more than just a technological advancement. It shows a change in agricultural extension where AI supports farmers in their expertise rather than replacing it. Bharat-VISTAAR is laying a foundation for a smarter, resilient and sustainable future for Indian agriculture through amalgamation of research, technology and governance in an integrated ecosystem.

The Green Revolution helped India feed its population; Bharat-VISTAAR can empower every farmer with the knowledge to shape the future of Indian agriculture. This could be the largest harvest in the march of Viksit Bharat 2047.

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Determinants of the Adoption of Digital Agricultural Extension Services among Fish Farmers in Rural India

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Abstract: *Digital agricultural extension services are increasingly advanced as a means of overcoming the reach, cost, and personnel constraints that limit conventional fisheries extension in India. Adoption among rural fish farmers nevertheless remains uneven and imperfectly understood, partly because the available evidence is drawn overwhelmingly from crop agriculture and extrapolated to aquaculture with little scrutiny. This review critically synthesises the determinants shaping the adoption and continued use of digital extension among inland fish farmers in rural India, organising them into socio-economic, technological, psychological, and institutional domains. Drawing meaningfully on Diffusion of Innovations theory, the Technology Acceptance Model, the Unified Theory of Acceptance and Use of Technology, and perceived behavioural control, it argues that adoption is governed less by access alone than by the interaction of infrastructure, trust, content relevance, and human intermediation. Persistent equity and sustainability gaps are identified.*

Keywords: *Digital Extension; Aquaculture; Technology Adoption; Fish Farmers; Fisheries Extension; Rural India*

1. Introduction

India is among the world's largest producers of fish, and inland aquaculture, concentrated in states such as Andhra Pradesh, West Bengal, Odisha, Assam, and Bihar, now contributes the major share of national output while supporting millions of small and marginal farmers (FAO, 2022). Conventional public extension is poorly placed to service this sector, constrained by unfavourable worker-to-farmer ratios and an institutional mandate historically fragmented between agriculture and fisheries departments (Glendenning et al., 2010). Digital agricultural extension, delivered through mobile advisories, applications, social-media groups, and helplines, has therefore been promoted as a scalable, low-cost complement to face-to-face advice (Aker, 2011). Yet the gap between the availability of such services and their sustained use by fish farmers remains wide. This review moves beyond description to interrogate why access does not reliably translate into adoption, and adoption into continued use.

2. Digital Agricultural Extension Services in the Fisheries Sector

Digital fisheries extension spans a heterogeneous set of channels: short-message and voice-based advisories, applications conveying water-quality, feed, seed, disease, and price information, moderated messaging groups, video repositories, and e-market platforms. A meaningful distinction separates marine capture fisheries, where ocean-state forecasts and potential-fishing-zone advisories dominate, from inland pond aquaculture, where advisory needs are more continuous and management-

intensive, spanning stocking density, aeration, feeding, and disease surveillance. Public initiatives, notably the Pradhan Mantri Matsya Sampada Yojana, the National Fisheries Development Board, and the fisheries institutes of the Indian Council of Agricultural Research, have begun to embed digital tools within delivery (Department of Fisheries, 2020). Critically, most operational platforms remain crop-first in design; genuinely species-specific, pond-level, and location-specific aquaculture advisories are comparatively scarce and frequently confined to pilots.

3. Determinants of Adoption among Rural Fish Farmers

3.1 Socio-economic and demographic determinants

Age, education, gender, fish-farming experience, household income, pond ownership, and farm size jointly condition both the capacity and the incentive to adopt. Younger farmers tend to be more receptive to digital tools, yet older and more experienced farmers often command the capital and pond assets that make information economically actionable; the influence of age is thus better read as interacting with experience and resource endowment than as linear (Mittal & Mehar, 2016). Education operates largely through digital literacy, while income and credit govern the affordability of devices and data. Gender is a critical equity fault line: women, though central to pond management, feeding, and post-harvest work, are systematically under-served by extension and under-equipped with smartphones. Pond tenure adds a subtler disincentive, since farmers on leased ponds may underinvest in information whose returns accrue partly to the landowner.

3.2 Technological and infrastructural determinants

Even strong motivation cannot override the binding constraints of access. Smartphone ownership, the reliability of mobile connectivity, and internet performance in interior fishing villages remain decisive. Although intense competition has made mobile data inexpensive in India, affordability is not the same as usable coverage, which stays patchy across the riverine and coastal tracts where many fish farmers operate. Content design matters equally: text-heavy interfaces in non-local languages exclude low-literacy users, whereas local-language, audio, and video formats widen reach. In the terms of the Unified Theory of Acceptance and Use of Technology, these are the facilitating conditions without which favourable intentions do not convert into use (Venkatesh et al., 2003); later extensions add price value and habit, constructs that map directly onto data affordability and routine use (Venkatesh et al., 2012).

3.3 Psychological and behavioural determinants

The acceptance literature locates the proximate drivers of adoption in perception. Perceived usefulness, in the Technology Acceptance Model, is not intrinsic to a platform but contingent on whether advisories are timely, species-appropriate, and location-specific; a generic alert carries little value for a carp-polyculture farmer facing a particular disease outbreak (Davis, 1989). Perceived ease of use interacts with digital literacy and language. Trust is arguably the pivotal construct: farmers weigh digital advice against the counsel of a trusted neighbour or input dealer, and confidence is earned only through demonstrated accuracy and coupling with human extension. Diffusion of

Innovations theory adds a fisheries-specific complication — observability is weak in pond systems, where an advisory's payoff is realised only at harvest, lengthening feedback and dampening the demonstration effects that normally accelerate diffusion (Rogers, 2003). Peer influence and social networks thus assume heightened importance.

3.4 Institutional, extension, and policy-related determinants

Adoption is ultimately embedded in institutions. Contact with fisheries extension personnel, Krishi Vigyan Kendras, and state fisheries departments, participation in training, access to credit and market information, and supportive government initiatives together shape whether digital tools are encountered, understood, and trusted. The construct of perceived behavioural control is instructive: a farmer's intention to use advisory becomes behaviour only when real facilitating resources — a working device, connectivity, affordable data, and institutional backing — are present, which is why positive attitudes so often fail to materialise as use (Ajzen, 1991). The most effective configurations are accordingly "phygital", blending digital delivery with human intermediation rather than substituting the former for the latter. Crucially, the supply of timely, location-specific advisories remains the institutional bottleneck on which most other determinants depend.

Socio-economic factors	Age · Education · Gender · Fish-farming experience · Household income · Pond ownership · Farm size
Technological access and digital literacy	Smartphone access · Mobile connectivity · Internet quality · Data affordability · Local-language content
Behavioural and psychological factors	Perceived usefulness · Perceived ease of use · Trust in advisories · Risk orientation · Peer influence · Social networks
Institutional and policy support	Extension contact · Training · Credit · Market information · Government initiatives · Timely location-specific advisories
Outcome	Adoption of digital agricultural extension services → Improved farm decision-making, productivity, income, market access, and resilience

Conceptual Framework of Determinants Influencing Adoption of Digital Agricultural Extension Services among Rural Fish Farmers

This figure arranges these determinants as a layered but interactive system: socio-economic and technological conditions are necessary yet insufficient enablers, behavioural acceptance mediates their conversion into use, and institutional support acts throughout as both enabler and moderator. Adoption is framed not as an end but as a pathway to improved decision-making, productivity, income, market access, and resilience, with outcome feedback reshaping subsequent behaviour.

4. Major Challenges in Adoption of Digital Fisheries Extension Services

The digital divide, structured by gender, age, literacy, and farm scale, reproduces existing inequalities, so the farmers most in need of advice are often least able to obtain it, while connectivity and electricity deficits persist in precisely the interior tracts where aquaculture concentrates. Content

relevance and quality remain uneven, and poorly validated advice risks eroding trust or propagating misinformation. Tellingly, rigorous evaluations of message-based agricultural information have found only modest effects on behaviour, underscoring that delivery alone seldom changes practice (Fafchamps & Minten, 2012). Many promising interventions remain trapped at the pilot stage, undermined by weak sustainability and limited scalability, while a fragmented fisheries mandate impedes coherent delivery and feedback from farmers stays thin. Underlying all of these is a sparse, largely crop-derived evidence base that constrains both design and evaluation.

5. Implications for Fisheries Extension Personnel, Policymakers, and Researchers

For extension personnel, the evidence favours blended models that treat digital tools as amplifiers of, not replacements for, trusted human contact, leveraging lead farmers and peer networks while building farmers' digital literacy. For policymakers, the priorities are rural connectivity, local-language and species-specific content, and inclusive design reaching women, smallholders, and tenant farmers; embedding such tools within existing schemes demands explicit sustainability and governance planning rather than recurrent piloting. For researchers, the need is for fisheries-specific, theoretically grounded, and longitudinal studies of continued use and downstream impact, disaggregated by gender, scale, and production system, so that adoption is understood as a socio-technical process rather than a discrete technological event.

6. Conclusion

The adoption of digital agricultural extension among rural fish farmers in India is fundamentally a socio-technical phenomenon. Access is necessary but never sufficient; trust, content relevance, and human intermediation are decisive, and equity and sustainability are integral rather than peripheral concerns. A critical reading of the determinants points firmly towards a blended, inclusive, and farmer-centred model as the realistic future of fisheries extension in the digital era.

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Digital Extension Approaches for Dairy Farmers and Livestock Management

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Abstract: *Rural dairy farming in India has long been anchored in smallholder production, where a single cow or buffalo often determines whether a household ends the month with surplus or deficit. The management demands of these animals are real and unforgiving — a missed heat, a delayed treatment, or a poorly balanced ration translates directly into lost income. Yet the extension infrastructure meant to guide farmers has consistently struggled to reach them at the right time and with the right advice. Digital extension has stepped into this gap. Using mobile phones, call centres, dedicated applications, video content, tele-veterinary services and, more recently, artificial intelligence, it offers a way to bring technical advisory closer to the farm and closer to the moment when it is actually needed. This review looks at what digital extension means in the livestock context, how it is being applied across India, what it can and cannot do, and where it is likely to go. A central argument throughout is that digital tools work best not as replacements for veterinarians and field workers but as mechanisms that make those professionals easier to reach and their advice easier to act on.*

Keywords: *digital extension; dairy farmers; livestock management; ICT; mobile advisory; e-GOPALA; Pashu Poshan; tele-veterinary services; artificial intelligence; animal health.*

1. Introduction

Ask any livestock officer in a district veterinary office what the hardest part of the job is, and the answer tends to be some version of the same thing: there are too many villages, too few staff, and the animals do not wait. A cow in reproductive distress at two in the morning does not benefit from advice that arrives three days later during a scheduled field visit. This is not a new problem, but it has become a more tractable one. Mobile penetration in rural India has grown to a point where even households without reliable road access often have a phone, and frequently have two. That shift in connectivity has created a genuine opening for extending livestock advisory beyond the boundaries of what office-based extension systems could historically manage (Food and Agriculture Organization [FAO], 2023).

Dairy farming occupies a particular place in rural livelihoods because of its daily income rhythm. Crop farming pays at harvest; dairy pays every day milk is sold. That regularity matters enormously for households managing tight cash flows, and it is why smallholder farmers — women especially — tend to treat the dairy animal as both a productive unit and a form of savings. The management of that animal is correspondingly intensive. Feeding, oestrus detection, artificial insemination timing, calf care, vaccination, deworming, udder hygiene and shed sanitation all require decisions that benefit from scientific guidance (FAO, 2023). When that guidance is absent or delayed, output falls and animal

welfare suffers. Digital extension is not a silver bullet for any of this. But applied carefully, it can make the gap between what farmers know and what they need to know considerably smaller.

India's national milk output reached 247.87 million tonnes in 2024–25 (Press Information Bureau [PIB], 2025), a figure that reflects decades of investment in the dairy sector. Sustaining and building on that output will require extension services that can operate at the same scale — something that conventional field-based systems alone are structurally ill-placed to deliver. This review examines how digital tools are being deployed in the Indian livestock sector, what the evidence says about their value, and what conditions need to be in place for them to work.

2. What Digital Extension Means in the Livestock Context

The term digital extension covers a wide range of activities, which is part of why it can seem vague. At its narrowest, it might mean sending a monthly SMS reminder about deworming schedules. At its broadest, it encompasses AI-driven decision-support systems that draw on real-time sensor data from individual animals. What these approaches share is the use of digital communication infrastructure to move technical information from institutions and experts to producers — and, increasingly, back again (FAO, 2023).

In livestock management specifically, this matters because the information needs are highly dynamic. A pregnant cow in her third trimester needs different guidance than a freshly calved one. A farmer dealing with suspected mastitis needs urgent diagnostic support, not a general brochure on udder health. Static, one-directional extension — the pamphlet left at the cooperative office, the training camp held twice a year — simply cannot respond to that variability. Digital platforms can, at least in principle, because they allow for segmentation by animal type, production stage and query, and because they allow farmers to initiate contact rather than waiting for the system to reach them (National Dairy Development Board [NDDB], n.d.-a).

It is worth being clear about what digital extension cannot substitute. Physical examination remains the foundation of veterinary diagnosis. Trust between a farmer and an extension worker is built over repeated face-to-face contact, not through a WhatsApp message. And the best digital advisory in the world is useless if the recommended input — a vaccine, a mineral supplement, a quality bull semen dose — is not available locally. Digital extension therefore functions most effectively when it is embedded in, and supported by, functional field-level service delivery systems.

3. Why the Need Is Pressing

The case for digital extension in dairy farming rests on several converging pressures. Disease burden is perhaps the most urgent. Foot-and-mouth disease, lumpy skin disease, mastitis, brucellosis and parasitic infestations continue to impose significant economic losses on Indian dairy households, and early warning and rapid response are central to limiting those losses (Department of Animal Husbandry and Dairying [DAHD], 2025). Vaccination coverage under national disease-control

programmes depends partly on farmers being reached at the right time — which is exactly where digital reminder and communication systems add value.

Feeding inefficiency is a less dramatic but probably more pervasive source of lost productivity. Feed costs account for sixty to seventy percent of total milk production costs in many smallholder systems, yet ration formulation is rarely done scientifically. Animals are either underfed, limiting their productive potential, or fed expensive concentrates without nutritional balancing. Digital ration-balancing tools — of which NDDB's Pashu Poshan application is the leading example in India — address this directly by helping farmers use locally available feed resources more efficiently (NDDB, n.d.-b). Reproductive efficiency tells a similar story. Long calving intervals, missed oestrus events and delayed artificial insemination all have calculable costs that better information management can reduce.

Women dairy farmers deserve specific mention here. They perform the majority of routine animal care work — feeding, cleaning, milking, calf management — yet they are consistently underrepresented in formal extension contact. Mobility constraints, household responsibilities and the timing of training events all work against their participation. Digital advisory delivered through mobile phones, particularly through voice and video rather than text, offers a way to reach them that conventional extension does not (FAO, 2023). This is not merely an equity argument; it is a productivity argument, because the person doing most of the management work is also the one who most needs reliable information.

4. The Principal Digital Extension Approaches

Mobile-based advisory through SMS, voice calls and WhatsApp remains the workhorse of digital livestock extension in India. Its advantages are obvious: most rural farmers have phones, the technology requires no special application, and messages can be sent in regional languages at low cost. The Government of India's mKisan portal has operationalised this at national scale, delivering crop and livestock advisories to registered farmers (Government of India, n.d.-b). The limitation is equally obvious: a message that arrives at the wrong time, or is too technical, or is in a language the farmer only partially reads, does little good. Message design matters as much as message delivery.

Kisan Call Centres address the interactivity gap that SMS cannot fill. Operational across extended daily hours and covering animal husbandry among other agricultural sectors, these centres let farmers articulate their problem in their own words and receive a response calibrated to their specific situation rather than a generic advisory (Government of India, n.d.-a). For farmers who are not comfortable with applications or who face a situation that does not fit a standard template, a knowledgeable person on the other end of the phone remains irreplaceable.

Dedicated mobile applications represent a more structured approach. The e-GOPALA platform developed by NDDB integrates information on livestock management practices, disease-free germplasm sourcing, artificial insemination services, animal nutrition and ethno-veterinary guidance

within a single interface (NDDB, n.d.-a). Pashu Poshan focuses specifically on ration balancing, allowing farmers to input locally available feed ingredients and receive a scientifically calculated ration recommendation for their animals (NDDB, n.d.-b). These applications work well for farmers with reasonable smartphone literacy, but they require sustained institutional investment in content updating and platform maintenance to stay relevant.

Video-based extension has proved particularly effective for skill transfer. Showing a farmer how to correctly strip a cow's udder before milking, how to detect early mastitis signs, or how to prepare silage is far more effective through a well-produced short video than through any amount of written description. Videos shared through WhatsApp groups and YouTube can be rewatched, shared laterally among farmers and accessed at the moment the skill is actually needed — not a week after a training camp (FAO, 2023). Tele-veterinary services extend professional reach further still, allowing farmers to share photographs or short video clips of clinical signs and receive a preliminary professional assessment. The Bharat Pashudhan platform represents the ambition to integrate these various streams — animal identity, health records, breeding data, service history — into a unified national digital livestock ecosystem (Bharat Pashudhan, n.d.). Whether that ambition is fully realised will depend on implementation quality and institutional continuity rather than the technology itself.

5. Where Digital Extension Is Being Applied

Across the production cycle, digital tools are finding application at multiple points. In nutrition management, ration-balancing applications like Pashu Poshan help farmers move from habitual to calculated feeding, with downstream benefits for milk yield, reproductive performance and feed cost per litre of milk produced (NDDB, n.d.-b). In reproductive management, mobile reminder systems alert farmers to expected oestrus dates and pregnancy check timelines, reducing the proportion of animals that miss a cycle due to inattention rather than infertility. In health management, digital vaccination schedules and disease alert systems support both individual farm prevention and population-level disease surveillance (DAHD, 2025).

Clean milk production is another area where digital advisory has clear application. Mastitis is among the most economically significant diseases in dairy herds, and a substantial proportion of cases are preventable through correct milking hygiene. Short instructional videos on hand washing, teat cleaning, equipment sanitation and post-milking teat dipping can be delivered directly to the farmer's phone without requiring a visit from an extension worker. Automated milk collection unit data — which record fat percentage, solids-not-fat and volume electronically — create accountability mechanisms that incentivise quality improvement when they are linked to differential payment (NDDB, n.d.-a). At the farm economics level, simple digital record-keeping can reveal cost and return patterns that farmers would not otherwise see, enabling more rational decisions about which animals to retain, which to cull and where feed expenditure is poorly allocated.

6. What the Benefits Actually Are

The most straightforward benefit of digital extension is reach. A broadcast advisory can contact tens of thousands of farmers in a matter of minutes, at a cost that field-based extension could not approach. During the outbreak of lumpy skin disease in 2022, for instance, the ability to push accurate biosecurity information to farmers rapidly through digital channels arguably limited spread in areas with functioning advisory networks (DAHD, 2025). Timeliness matters enormously in livestock management — advice on heat-stress management is valuable before summer peaks, not after animals have already suffered production decline.

Beyond reach and timing, digital systems offer continuity that episodic field visits cannot provide. A farmer who attends a training camp in February and does not speak to an extension officer again until September is managing largely on memory and habit. Periodic digital reminders on vaccination, deworming, mineral supplementation and breeding dates keep key management tasks in view throughout the year. When advisory is linked to digital records — as it can be in systems like e-GOPALA — it can also be personalised to the specific animal and production context rather than being generic. Institutional transparency improves when cooperative milk collection records are digitised; disputes over fat measurement and payment become less frequent, and farmer confidence in cooperative systems tends to increase. For programme planners, digital interaction data provide a form of needs assessment that structured surveys rarely match, revealing what farmers are actually worried about at any given time and where service gaps are most acute.

7. The Constraints That Matter

It would be a disservice to the subject to catalogue the benefits of digital extension without taking its limitations seriously. Digital literacy is an unresolved constraint across much of the smallholder population. A farmer who has never used a smartphone beyond calls and WhatsApp voice messages is unlikely to navigate a multi-function livestock management application without support, and the support required is not a one-time orientation session but sustained, patient handholding (FAO, 2023). This is a resourcing question that digitisation enthusiasts often underestimate.

Connectivity is a related structural problem. The assumption that rural India has adequate internet access is not uniformly correct. Signal quality is inconsistent, data costs matter in household budgets stretched thin by input prices, and many farmers shift between areas with and without reliable coverage. An extension system that works only when 4G is available will fail precisely in the places where conventional extension also fails — which is where the need is usually greatest. Offline functionality, SMS fallback and voice-based alternatives are not optional add-ons but design requirements for genuinely inclusive digital extension.

Content quality and local relevance deserve more critical attention than they typically receive. A ration recommendation developed for crossbred cattle in Punjab does not translate directly to the feeding context of a Gir cow on a dry-land farm in Saurashtra. A disease alert calibrated for the epidemiological profile of one region may cause unnecessary alarm or false reassurance in another. The tendency to develop advisory content centrally and distribute it uniformly is efficient but

epistemically problematic. Farmers know this, and when they notice that advice does not match their reality, trust erodes quickly. Misinformation is the other side of this coin. Social media platforms that distribute legitimate advisory from cooperatives and veterinary departments also distribute unverified drug recommendations, fake remedies and misleading product promotions with the same ease (FAO, 2023). Expert moderation is necessary but labour-intensive, and most institutions are not adequately resourced to do it well.

Sustainability, finally, is the constraint that programme evaluations tend to raise and funders tend to underweight. Digital extension initiatives that are lively during a project period and dormant twelve months after funding ends have produced technology rather than institutional change. The difference lies in whether digital systems are integrated into existing institutional workflows or run in parallel to them.

8. Future Directions and Conclusion

The direction of travel in digital livestock extension points toward greater personalisation, better data integration and more sophisticated decision support. AI-based chatbots capable of responding to farmer queries in regional languages are already in development and early deployment in some contexts. Image-based tools that can assist in preliminary identification of visible clinical signs — skin lesions, hoof problems, eye conditions — are technically feasible and could substantially extend the reach of veterinary advisory in areas with weak professional coverage. Wearable biosensors that monitor individual animal activity, rumination and body temperature offer the prospect of early disease and oestrus detection before clinical signs are visible to the farmer, though the economics of these technologies remain prohibitive for most smallholder operations without cooperative or shared-service models. The Bharat Pashudhan platform signals the institutional recognition that fragmented digital systems — one app for nutrition, another for breeding records, a third for insurance — are less useful than integrated architectures that link animal identity, health history, service records and scheme eligibility in ways that both farmers and institutions can interrogate (Bharat Pashudhan, n.d.). Climate change adds urgency to all of this. Heat waves of increasing intensity, shifting fodder availability, and changing vector distributions will require livestock advisory systems that are faster, more location-specific and more frequently updated than anything the conventional extension model can deliver.

Digital extension has genuinely changed what is possible in dairy and livestock advisory services. Farmers who once waited weeks for a veterinary visit can now access preliminary guidance within minutes. Cooperatives that once estimated milk volumes by eye now record fat, SNF and volume electronically with every collection. Breeding records that existed only in farmers' heads — and often nowhere at all — can now be maintained digitally and used to trigger timely reminders. These are real improvements with real consequences for productivity and income. The caution is that none of them work without institutional commitment, content quality, field-level human linkage and honest attention to who is and is not being reached. Digital extension is a tool. Its value is determined not by the sophistication of the technology but by how carefully it is fitted to the people it is meant to serve.

The New Currency of Agriculture: Data, Carbon and Intelligence

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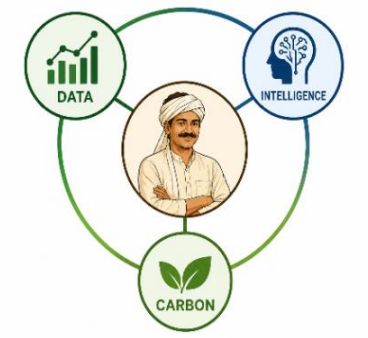
For centuries, farming depended on rich land, rain arriving at the right time and hard work. Now that vision is taking on new dimensions. In times of climate change, digital innovation and artificial intelligence, supporting farmers means giving them information, technology and new sources of income. The future of Indian agriculture would be determined not by the size of landholdings or quantity of harvests but by three emerging assets — Data, Carbon and Intelligence. Together, they are the new currency of Indian agriculture.

This changing philosophy is reflected in the Union Budget 2026-27. The Government of India has emphasized technology-led growth, climate resilience and value addition and not looking at agriculture only through the lens of subsidies and production. Among the biggest announcements is Bharat-VISTAAR (Virtually Integrated System to Access Agricultural Resources) — a multilingual Artificial Intelligence platform which will integrate AgriStack, ICAR Package of Practices, weather information, soil data and market intelligence to provide personalised advisory to farmers. This initiative is a paradigm shift from broad-based recommendations to data-driven, location-specific decision support, putting scientific knowledge directly in farmers' hands. (PRS Legislative Research)



Data is at the core of this change. Every soil test, every satellite image, every weather forecast, every crop survey and every market transaction creates an ever-expanding digital ecosystem. India is building a comprehensive agricultural data infrastructure through AgriStack and the Digital Farmer Registry that enables better targeting of government schemes, transparent service delivery and evidence-based farm management. Soon enough, farm data could be as valuable as the crops themselves, giving farmers access to tailored credit, insurance, advisory services and markets more efficiently.

The second new currency is carbon. Agriculture is no longer seen only as a source of greenhouse gas emissions, but also as a powerful solution to climate change. Sustainable methods, such as conservation tillage, agroforestry, residue management, cover cropping, and soil health improvements,

can sequester atmospheric carbon and store it in the soil. With the development of carbon markets these environmental services can provide an additional source of income through carbon credits. Digital technologies such as satellite imagery, drones, remote sensing and AI-based Measurement, Reporting and Verification (MRV) systems enable accurate measurement and verification of carbon sequestration, unlocking new economic opportunities for Indian farmers.

The third currency is intelligence — not just human intelligence, but the power of Artificial Intelligence. Modern artificial intelligence systems can analyse weather patterns, soil fertility, pest outbreaks, market prices and historical yield data all at once to suggest the best course of action for each farmer. With the introduction of Bharat-VISTAAR, India announces its resolve to democratize such intelligence by putting advanced AI in multiple Indian languages. AI will not replace agricultural scientists or extension professionals, but will enhance their ability to give timely, accurate and customized advice to millions of farmers.

This change also changes the role of agricultural institutions. Krishi Vigyan Kendras, Farmer Producer Organizations, agritech startups and extension agencies are not just the channels of technology transfer now but are emerging as collaborators to build a digitally connected agricultural ecosystem. Their success will depend more and more on how well they can combine scientific know-how with digital innovation.

India has seen some remarkable agricultural revolutions, from the Green Revolution which resulted in food security to the White Revolution which changed milk production. The next revolution is going to be measured in terabytes of agricultural data, tonnes of carbon sequestered in soil and smart decisions powered by AI, not just in tonnes per hectare. As India moves towards Viksit Bharat 2047, the biggest agricultural wealth of the country may not be hidden just under the soil but also above it, the carbon in it and the intelligence that connects them. Data, carbon and intelligence are going to be the real currency of Indian agriculture in this new era.

Bridging the Digital Divide: Why Smallholder Farmers Are Left Behind in Digital Agriculture

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In a village, a farmer named Ramesh still checks the sky before he checks anything else. He has heard about apps that predict rainfall, sensors that tell you exactly when a crop needs water, and drones that can spot disease before the human eye ever could. He has heard about them the way most of us hear about places we will probably never visit — interesting, distant, not quite real.

This is the quiet contradiction sitting at the heart of the digital agriculture revolution. While agri-tech startups raise millions and satellites map soil moisture from space, nearly 500 million smallholder farmers around the world are still making decisions the way their grandparents did — by instinct, memory, and hope.

It's not that they don't want better tools. It's that better tools were never really built for them.

The gap isn't about willingness. It's about access.

Start with the basics: a smartphone. In many rural regions, owning one is still a luxury, and a stable internet connection is even rarer. Even when both exist, most digital agriculture platforms are designed in English or in formal regional languages, dense with technical jargon that assumes a level of literacy or comfort with technology that many farmers simply haven't had the chance to build.

Then there's the money. Precision sensors, satellite subscriptions, and smart irrigation systems are often priced for commercial farms, not for someone cultivating two acres of land with a thin margin for error. Asking a smallholder farmer to invest in a costly sensor is asking them to bet next season's food security on an unfamiliar gadget.

And even when the technology is affordable, trust doesn't come with the download. Farming knowledge has been passed down for generations through relationships — with neighbours, with local extension officers, with the land itself. A notification on a screen doesn't carry the same weight as advice from someone who has walked the same fields.

Why this matters more than we think

Smallholder farmers aren't a small footnote in global agriculture — they produce roughly a third of the world's food. Leaving them out of the digital shift doesn't just widen inequality; it slows down the very progress digital agriculture promises. Climate resilience, efficient resource use, better yields — none of it scales if the majority of farmers are left holding paper and guesswork while the rest of the industry moves to data and precision.

Closing the gap, not just talking about it

The fix isn't more technology. It's better-designed technology — tools built in local languages, priced for small budgets, distributed through people farmers already trust, and taught through demonstration rather than manuals. Government-backed digital agriculture missions, community-led training, and shared-resource models (where a village accesses one drone or one weather station together) are already showing promise in parts of India, Africa, and Southeast Asia.

Digital agriculture doesn't fail because the technology isn't good enough. It fails when it forgets who it was supposed to help first.

Ramesh doesn't need a revolution. He needs someone to hand him the future in a language, and at a price, that actually reaches him.

Agricultural Extension in the Digital Era: The Role of e-NAM

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Samprasaran is a Sanskrit word carrying the weight of hope of distribution of knowledge in Agriculture.

Given today's era of digital culture, we all are freemen of digitisation. Freedom of digitisation is enjoyed only when it's dispersed in a systematic and proper manner among all the participants of society.

e-NAM (Electronic National Agriculture Market) holds the record of soft-launching our Indian agriculture into the field of advanced digital society. A name occupying less pages in our notebooks and diary, instead affecting the lives of the people who feed our nation.

A platform uniting our scattered markets into a consolidating stage where freedom and transparency are valued more. A platform for happiness where post-harvest joy is brought back to the household just like our forefathers' days.

e-NAM promotes the samprasaran that our agriculture market needs for stability of our nation's crop growers.

We the whole nation depend on the food that our farmer friends grow for us; it is very important that stability is ensured within their eco-systems. It is the responsibility of the visible and invisible workforces involved in Agriculture to work toward educating and spreading platforms like e-NAM.

The digital portal for National Agriculture Market doesn't only allow simple digitisation, but it simultaneously provides our farmers' choices and options to choose, gives them a voice to say over prices they have worked hard for throughout the season.

India's own indigenous digital baby has extended its samprasaran to over 18 million farmers' households and contributed to helpful supply-chain smoothness by adding 0.27 million purchasers around the nation.

The Ministry of Agriculture and Farmers' Welfare is consistently supervising the state authorities and micro-level authorities who are involved in the samprasaran and bring innovation into the chain of systems.

Digital Expertise For The Field: The Role Of Expert Support Systems In Agricultural Extension

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Agricultural extension workers travel from research stations to farms to translate the scientific knowledge of agriculture into practical use to the farmers. But extension personnel face limitations like the need to travel long distances, and thus the dispersion of knowledge slows down and the farmers do not receive the knowledge at the proper time. Hence this gap is minimized by the expert support system, also known as the agricultural expert system.

An expert support system is a branch of artificial intelligence which deals with the specialized knowledge of domains (like agronomy, plant pathology, entomology, extension, etc.) structured into a knowledge base. The system then uses an inference engine to reason through this knowledge base, much as a human expert would, to answer queries or solve problems presented by a user. Unlike other databases, an expert support system doesn't only state facts but also gives logical reasons for those facts to reach a conclusion. It also helps to explain the reasons and give solutions to solve specific situations. For example, a farmer notices strange yellow spots spreading through the tomato leaves. Instead of waiting for an extension worker to visit the land and diagnose the problem, with the help of the expert support system the farmer can simply photograph the spots and learn about the disease and its management.

Core Components of ESS

- Knowledge Base: This is the core of the system. It holds facts, rules, and guidelines gathered from agricultural scientists, published research, and experienced practitioners.
- Inference Engine: This part uses logical reasoning based on the knowledge base in response to user input. It usually relies on rule-based reasoning (if-then logic).
- User Interface: Since end users range from educated researchers to farmers with limited tech skills, the interface often has simple menus, voice interaction, regional language support, and mobile applications with image-recognition features.

Benefits to Agricultural Extension

- Wider reach: One well-built knowledge base can stand in for a whole team of specialists, answering thousands of farmers at once.
- Consistency: A system doesn't have a bad day or forget a detail the way a tired officer might after a long week of field visits, so the advice doesn't depend on who happens to pick up the phone.

- Round-the-clock help: These systems don't keep office hours, so a farmer who spots a pest outbreak at ten at night doesn't have to wait until morning to do something about it.
- Lower cost: Sending someone out to a farm in person is expensive; a digital consultation is a fraction of that price.

Challenges and Limitations

- Hard to build: Getting a knowledge base right takes real, ongoing collaboration with domain experts, and that kind of sustained partnership isn't cheap or quick to put together.
- Access gaps: Even when the system itself is solid, plenty of farmers — especially in remote areas — simply don't have dependable internet or a smartphone to reach it in the first place.
- Language and literacy barriers: An interface that assumes a certain reading level or a particular language will inevitably leave some farmers behind.
- Local context matters: Farming conditions can shift dramatically from one valley to the next, so advice trained on data from one agro-climatic zone can fall flat — or worse, mislead — when applied elsewhere without adjustment.

Drone Technology in Various Agricultural Operations

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Drone technology is nowadays one of the most important topics used in the digitalization of various agro operations. Many farmers now follow the principles of Low External Input Sustainable Agriculture, one of which is Precision Agriculture, which estimates field variability and enables application of inputs through Variable Rate Technology. In this context, drone technology is used for the uniform application of inputs over fields. Western countries mainly practice this kind of technology for input management to save time and address field variability. But in India, mainly marginal and small farmers dominate, and the land is highly fragmented, making such tech-driven operations difficult to perform. In recent years, however, the number of investors and entrepreneurs entering agriculture as a primary field of investment has increased. This kind of investment produces contract farmers where the land is owned by the company, and it is in these areas that technology-oriented farming practices mainly take place.

Agricultural Drones

Agricultural drones are unmanned aerial vehicles used to boost farm output through precise crop spraying, multispectral health mapping, and efficient field monitoring.

By using drones, targeted spraying is also done, by which fertilizers, fungicides, pesticides and herbicides are applied only to the targeted plant or plants without a blanket application to the whole field area.

Crop scouting is also carried out by drones: multispectral cameras track plant health and pinpoint pest issues early, helping identify unhealthy plants within a whole community of plants without any human intervention in the field.

Efficient spraying is achieved through drone technology because it uses variability maps of the whole field area and applies inputs on a variable-rate basis. Variability within the field is identified by remote sensing, and these variability maps are loaded into the drone to guide the variable rate of input applied to different spots.

Drone Technology in the Indian Scenario

India's drone ecosystem is rapidly expanding under liberalized regulations and government initiatives, featuring over 38,500 registered drones, nearly 39,900 certified remote pilots, and major growth across agriculture, defense, and governance.

The Namo Drone Didi scheme empowers women self-help groups by distributing agricultural drones for precision spraying and crop monitoring. The government promotes drone adoption through financial aid and schemes aiming to supply drones to rural women's self-help groups.

The SVAMITVA Scheme has digitally mapped hundreds of thousands of villages to generate legal property cards and minimize land disputes.

Advantages of Drone Technology in Agriculture

- Drones collect high-resolution images to identify variations in crop growth, soil moisture and nutrient status, enabling site-specific management.
- Using RGB, multispectral or thermal cameras, drones can detect nutrient deficiencies, pest infestations, diseases and water stress before symptoms become visible.
- Drone spraying ensures uniform application, reduces chemical wastage, minimizes human exposure to pesticides, and is especially useful in inaccessible fields.
- Drones help identify areas of water stress, irrigation leaks and poor drainage, improving irrigation efficiency.
- Farmers can quickly inspect large areas, saving time and labor compared with manual field surveys.
- Drone imagery helps estimate crop biomass, plant population and expected yield, aiding harvest planning.
- Drones generate detailed maps of soil variability, topography, slope and drainage patterns for better land management.
- They identify weed-infested patches, allowing targeted herbicide application and reducing herbicide use.
- Some agricultural drones can broadcast seeds, fertilizers or cover-crop seeds over large areas rapidly.
- Drones perform monitoring and spraying tasks quickly, addressing labor shortages and lowering labor costs.
- Large farms can be surveyed within minutes, allowing timely management decisions.
- Early detection of problems and precise input application increase crop yield and reduce production costs.
- Precision application reduces chemical runoff, conserves water and lowers environmental pollution.
- Drones rapidly assess damage from floods, droughts, hailstorms, cyclones or pest outbreaks, helping in insurance claims and recovery planning.

Digital Inclusion in Agricultural Extension

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Introduction

Digital inclusion in agricultural extension refers to ensuring that all farmers, irrespective of their age, gender, education, income, or geographical location, have equal access to digital technologies, internet connectivity, digital literacy, and agricultural advisory services. With the rapid advancement of Information and Communication Technologies (ICTs), agricultural extension has shifted from conventional face-to-face communication to digital platforms such as mobile applications, online portals, artificial intelligence (AI), and social media. Digital inclusion ensures that these innovations benefit every farmer, especially small and marginal farmers, thereby improving agricultural productivity and rural livelihoods.

Importance of Digital Inclusion

Digital inclusion increases the effectiveness and outreach capability of agricultural extension programs through the provision of information on weather forecasting, agricultural practices, pest and disease management, price of crops, and government policies. This makes the process of communication between farmers, scientists, and extension workers fast and at lower costs than the traditional extension approach. Digital tools make information sharing easier, help farmers make better decisions and adopt modern agricultural practices. Digital inclusion equally empowers women, youth in rural areas, and vulnerable groups through equal access to agricultural information.

Some emerging digital technologies that have changed agricultural extension practices are artificial intelligence (AI), which gives personalized advisory services for crops and pest analysis, and IoT, which facilitates monitoring of soil moisture, weather, and crop condition through sensors. Drones and remote sensing technologies help in crop monitoring and precision agriculture. Mobile apps, social media platforms, and digital knowledge portals offer expert guidance, learning resources, and market information to farmers whenever and wherever they need it. These technologies have made agricultural extension practices efficient and demand-oriented.

Challenges and Way Forward

Even though much has been accomplished in the area of digital inclusion, some challenges remain. Firstly, lack of internet connectivity and insufficient digital infrastructure in rural areas prevent farmers from accessing digital services. Most marginal and small farmers lack the capacity to buy smartphones or pay for internet data. Secondly, low levels of digital literacy among elderly and female farmers limit the use of digital technology. Another challenge faced by farmers is the language barrier, since most digital platforms are not offered in local languages.

For the realization of digital inclusion in agricultural extension services, concerted efforts must be made by government, research institutions, extension organizations, and private organizations. There is a need to invest in rural internet connectivity, reliable power supply, and affordable digital gadgets.

Conclusion

Digital inclusion is crucial for creating an effective and sustainable agricultural extension system. It allows farmers to acquire information on time, adopt better technologies, and take appropriate actions in agriculture. Despite existing barriers like inadequate infrastructure, low digital literacy, and high cost of technology, investments in these areas, coupled with relevant policies, can close the digital divide. Improved digital inclusion will not only boost the productivity and incomes of farmers but will also be instrumental in achieving sustainable rural development.

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Harnessing Decision Support Systems in Agricultural Extension: Navigating Uncertainty with Intelligence

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Introduction

Farming is an intricate dance of decision-making, where choices about what to plant, when to irrigate, and how much fertilizer to apply can significantly impact a farmer's success. Unlike the predictable environment of a factory, agriculture is fraught with uncertainties—erratic weather patterns, pest invasions, and fluctuating market prices can all lead to devastating losses, particularly for small-scale farmers who lack the financial cushion to weather such storms.

Traditionally, agricultural extension services have aimed to bridge this gap by transferring research-based knowledge from scientists to farmers. However, the ever-increasing complexity and volume of agricultural information have made it challenging for extension workers to keep pace. This is where Decision Support Systems (DSS) come into play. A DSS is essentially a computer-based tool that assists decision-makers in tackling complex or semi-structured problems by integrating data, analytical models, and expert knowledge to generate a range of potential options. It's crucial to note that while DSS provides valuable support, the ultimate decision-making power rests with the farmers.

Evolution of DSS in Agriculture

The evolution of DSS in agriculture has mirrored the broader technological advancements in farming. It can be categorized into four key stages: Agriculture 1.0 relied solely on manual and animal labor; Agriculture 2.0 introduced machinery and chemical inputs following the industrial revolution; Agriculture 3.0 saw the advent of computers and early robotics; and today's Agriculture 4.0 is characterized by the integration of the Internet of Things, Artificial Intelligence, Big Data, and remote sensing technologies. This evolution has transformed DSS from simple desktop tools to advanced web-based platforms and mobile applications, enabling AI-driven smart farming systems that provide real-time, location-specific advice. A robust agricultural DSS should be interactive, data-driven, model-based, and user-friendly, offering timely guidance without dictating actions.

Core Components and Applications in India

Most DSS comprise three core components: a database that includes weather, soil, market, and crop data; a model base that employs analytical or simulation models to process this data; and a user interface for farmers or extension workers to engage with the system. These systems can be classified into data-driven, model-driven, or knowledge-driven types, frequently applied in areas like farm mission planning, irrigation management, climate adaptation, and minimizing food waste. In India, various DSS platforms are already making significant contributions to agricultural extension. For

instance, Kisan Sarathi directly connects farmers with KVK scientists for personalized, real-time advice in local languages. Meanwhile, Kisan Suvidha offers crucial information on weather, market prices, and pest management through a user-friendly mobile app. Other initiatives, such as the mKisan/SMS portal, facilitate mass advisory messages to registered farmers.

Challenges

While DSS offers numerous benefits, such as timely advice and improved resource efficiency, challenges remain. Many systems are not user-friendly, access to digital tools can be uneven, and the systems often focus narrowly on specific tasks. Additionally, farmers may be reluctant to rely on digital advice without human validation, and many DSS initiatives face hurdles in maintaining financial sustainability.

The Way Forward

Looking ahead, future DSS are expected to become more intuitive and visually accessible, addressing not only immediate decisions but also long-term farm planning. Enhanced integration with real-time sensor data, AI forecasting, and multilingual voice interfaces will likely improve their usability. Ultimately, the role of extension professionals will remain vital, as they foster trust, adapt advice to local contexts, and provide the empathy and judgement that technology cannot replicate. By combining human expertise with digital intelligence, we can make agricultural decision-making more informed, resilient, and inclusive.

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Transforming Agricultural Extension through AI and AgriStack: Insights from the India AI Impact Summit 2026

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Introduction

The India AI Impact Summit, convened in New Delhi from 16–20 February 2026, offers a useful vantage point for examining the evolving relationship between artificial intelligence and agricultural extension in India. The summit drew over 35,000 registered participants from more than 100 countries, including heads of government, ministers, and industry leaders, underscoring an emerging global consensus around translating AI capability into measurable economic outcomes. This discussion situates AgriStack — India's principal agricultural data infrastructure — within that broader conversation, and considers both its achievements and the structural challenges that remain.

AgriStack as Digital Public Infrastructure

AgriStack could be considered as the basic digital identity infrastructure for Indian farmers. Land ownership information, livestock, cropping pattern, and eligibility to schemes are all connected to a special Farmer ID, allowing the better delivery of agricultural services. According to the latest government data, over 7.6 crore Farmer IDs were created, and the digital survey of crops was conducted on more than 23.5 crore plots. In comparison with the target number of 11 crore IDs by 2026-27, almost 1.9 crore IDs are issued to women farmers.

Bharat-VISTAAR and the Advisory Layer

The Union Budget of 2026-27 announced Bharat-VISTAAR, a proposal for multilingual artificial intelligence software meant to link up AgriStack data banks with ICAR's science-backed agriculture techniques, purportedly in order to provide customized advice and mitigate risks on the farm. Addressing the concurrent AI4Agri Summit, Dr. Jitendra Singh said this was not a fresh understanding of the challenges faced by the field of agriculture but a way to ensure the provision of all known information to farmers on a large scale – observing that even a mere ten percent increase in productivity amongst the around 600 million farmers of the Global South would be a significant reduction of poverty. He further emphasized compact regional AI algorithms that could work in rural settings without any high connectivity, as well as a future convergence of state-wise platforms into one “Agri Data Commons” for the nation.

Operational Applications

There are several operational AI-based applications that have been operational in recent times. For instance, the Kisan e-Mitra chatbot has served over 93 lakh farmers' questions since 2023 through 11 regional languages and there is a national system for monitoring pests that gives advisories on 66

crops to more than 10,000 extension workers. Other examples include YES-TECH and CROPIC which are insurance applications.

Critical Considerations

It is important, however, not to overstate the maturity of this ecosystem. A recurring concern in the literature is the absence of a clearly articulated, farmer-centric data ownership framework, which raises the possibility of misuse of sensitive land and financial data collected through AgriStack. Additionally, the high capital cost of precision-agriculture technologies remains difficult to reconcile with India's average landholding size of approximately one to 1.2 hectares. Commentary emerging from the summit suggests that progress toward Viksit Bharat 2047 will depend less on the proliferation of individual AI tools than on their coherent integration within a unified governance and data architecture strategy.

Conclusion

Taken together, these developments indicate that AI-driven agricultural extension in India is transitioning from isolated pilots toward infrastructural integration — though questions of data governance and equitable access remain unresolved and merit continued scholarly attention.

ICT News Bulletin: Digital Agriculture Update

A quick round-up of recent developments in information and communication technology (ICT) for agriculture, from India and around the world.

AgriStack and Bharat-VISTAAR Gather Pace

Discussions at AgroSpectrum Technovate 2026 highlighted how India's emerging digital public infrastructure for agriculture — anchored by AgriStack and the proposed multilingual AI advisory network Bharat-VISTAAR — is moving towards integrating farmer data, predictive analytics and advisory services into a single digital ecosystem, with policymakers and industry leaders describing it as a structural shift towards data-driven farming systems.

AI-Powered eNAM Upgrades Improve Price Discovery

The Electronic National Agriculture Market (eNAM) continues to be strengthened with advanced analytics, digital payments and AI-based supply-demand mapping, helping smallholder farmers access more transparent price discovery and reducing their dependence on intermediaries.

Drones and Precision Agriculture on the Rise

India's market for agricultural drones and remote-sensing services is projected to cross USD 600 million by 2026, driven by government-backed adoption schemes. Soil sensors, satellite imagery and drone-based spraying are increasingly enabling farmers to target inputs precisely rather than applying them uniformly across a field.

AgriTech India 2026 to Open in Bengaluru

The 17th AgriTech India exhibition, showcasing farm machinery, precision agriculture and agri-processing technologies, is scheduled for 21–23 August 2026 at the KTPO Exhibition Centre, Bengaluru — offering a platform for agri-startups and technology providers to present their latest innovations.

AI for Agriculture Takes Centre Stage at India AI Impact Summit

Following the India AI Impact Summit 2026 in New Delhi, the FAO and other UN agencies have continued to engage with Indian policymakers on scaling artificial intelligence from pilot projects to sustainable, large-scale solutions for food security and climate-resilient farming.

In Closing

"...as big a difference to the Third-World poor as literacy or high-yield agriculture."

— Sam Pitroda

Father of India's Telecom Revolution, ICT-for-development pioneer