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Review Article

Changing Paradigms in Agricultural Extension and Emerging Trends- A Review

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Abstract: Agricultural extension has undergone a significant transformation from conventional, technology-transfer-oriented approaches towards participatory, pluralistic, digital, climate-smart and market-oriented systems. This review examines the changing paradigms of agricultural extension and synthesizes the major developments that have influenced contemporary agricultural advisory services. The review focuses on participatory extension, Agricultural Innovation Systems, information and communication technologies (ICTs), digital agriculture, emerging technologies such as the Internet of Things (IoT), climate-smart extension, Farmer Producer Organizations (FPOs), market-oriented advisory services, public–private partnerships and inclusive extension approaches. The reviewed literature indicates that modern extension increasingly functions as a knowledge-sharing, innovation-facilitation and coordination mechanism involving farmers, research institutions, government agencies, private organizations and other stakeholders. Digital technologies have expanded the reach and timeliness of advisory services, while participatory approaches have strengthened farmer involvement and local learning. Climate-smart extension has further broadened the role of advisory services towards resilience and sustainable resource management, whereas FPOs and market-oriented approaches have connected farmers with collective action, value chains and markets. However, challenges including the digital divide, inadequate infrastructure, limited digital literacy, institutional coordination, financial constraints and unequal access to advisory services continue to restrict the effectiveness of emerging extension systems. The review highlights the need for integrated extension models that combine digital technologies with participatory approaches, institutional collaboration, climate-smart practices and market linkages to create more effective, inclusive and sustainable agricultural advisory systems.

Keywords: Agricultural Extension; Agricultural Advisory Services; Digital Agriculture; ICT; Participatory Extension; Agricultural Innovation Systems; Climate-Smart Agriculture; Farmer Producer Organizations; Market-Oriented Extension; Public–Private Partnerships.

1. Introduction

Agricultural extension plays a vital role in connecting research institutions with farmers through knowledge sharing, capacity building and advisory services. Modern extension emphasizes farmer participation, digital tools, climate resilience, market orientation, entrepreneurship, sustainability and multi-stakeholder collaboration. Emerging technologies such as AI, remote sensing, drones, IoT, mobile advisory and big data are reshaping advisory services. Despite significant progress, constraints such as digital divide, limited infrastructure, shortage of trained personnel and

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2. Literature Review

Agricultural extension has undergone a substantial transformation from a predominantly linear technology-transfer model towards more participatory, pluralistic, demand-driven and innovation-oriented approaches. Traditionally, extension systems were largely based on the assumption that agricultural research institutions generated improved technologies and extension personnel subsequently transferred these technologies to farmers. However, this approach was increasingly considered inadequate for addressing the diverse agro-ecological, socio-economic and institutional conditions under which farmers operate. The changing nature of agriculture, increasing commercialization, environmental concerns and the emergence of new communication technologies have consequently encouraged a broader understanding of extension and advisory services.

2.1 Evolution from Technology Transfer to Pluralistic Extension

The evolution of agricultural extension reflects a gradual shift from expert-driven technology dissemination towards systems that recognize farmers as active participants in agricultural innovation. Earlier extension approaches primarily emphasized the transfer and adoption of technologies developed by research institutions. Over time, limitations associated with one-way communication and insufficient consideration of farmers' local knowledge encouraged the development of participatory and demand-driven approaches.

Birner et al. (2009) proposed a "best-fit" framework for agricultural advisory services, emphasizing that extension systems should be designed according to specific institutional, organizational and socio-economic conditions rather than following a single universal model. This perspective contributed to the recognition of pluralistic extension systems in which public agencies, private organizations, non-governmental organizations, farmer organizations and other stakeholders can jointly provide advisory services.

Norton and Alwang (2020) further observed that agricultural extension has changed considerably because of structural changes in agriculture, fiscal constraints on public extension systems, decentralization and the emergence of information and communication technologies (ICTs). These changes have contributed to the development of pluralistic advisory systems involving both public and private actors. Farmer groups and virtual networks have also increasingly become important mechanisms for knowledge dissemination and technology adoption.

Thus, contemporary agricultural extension is no longer restricted to a government-to-farmer communication channel. Instead, it increasingly represents a network of organizations and actors involved in knowledge generation, dissemination, adaptation, innovation and market development.

2.2 Participatory Extension and Farmer-Centred Approaches

Participatory extension emerged as an important response to the limitations of conventional top-down approaches. In participatory systems, farmers are considered active contributors to the identification of problems, experimentation, evaluation and adaptation of agricultural technologies. Farmer Field Schools (FFSs), participatory technology development and community-based learning have therefore become important components of farmer-centred extension.

Van den Berg et al. (2020), through a qualitative review of 65 studies selected from 218 screened studies, found that Farmer Field Schools can contribute to outcomes across human, social, natural and financial domains. Their findings indicate that participatory learning can extend beyond simple knowledge transfer by strengthening farmers' decision-making capabilities, social interaction and capacity to respond to field-level problems.

However, the effectiveness of participatory approaches depends considerably on how participation is implemented and evaluated. Studies have pointed out that some programmes continue to operate primarily as technology-transfer interventions even when they are formally described as participatory. Consequently, meaningful participation requires farmers to have an active role in experimentation, learning and decision-making rather than merely receiving information from extension personnel.

The participatory paradigm therefore represents a significant change in the philosophy of agricultural extension, moving the emphasis from "transferring technologies to farmers" towards "learning and innovating with farmers."

2.3 Agricultural Innovation Systems and Multi-Stakeholder Collaboration

The Agricultural Innovation Systems (AIS) perspective has further broadened the role of extension by recognizing that agricultural innovation results from interactions among multiple actors rather than from research institutions alone. Farmers, researchers, extension organizations, private companies, NGOs, financial institutions, government agencies and market actors can all contribute to the innovation process.

Klerkx et al. (2012) highlighted this transition from conventional research-push models towards research-pull and collaborative approaches. According to the innovation systems perspective, extension organizations increasingly perform the role of knowledge brokers and innovation facilitators by establishing linkages among different actors. Extension consequently becomes concerned not only with technology dissemination but also with facilitating collaboration, coordination and institutional change.

This approach is particularly relevant to complex agricultural problems such as climate change, natural-resource management, value-chain development and commercialization, where solutions require cooperation among multiple stakeholders. The innovation systems perspective has therefore contributed to the transformation of extension from a relatively linear communication function into a broader process of facilitation and coordination.

Research on agricultural extension in India has similarly emphasized the need for reorientation of extension research and practice in response to changing agro-climatic, socio-economic and institutional conditions. Pluralism and greater contextualization have become increasingly important for improving the relevance and effectiveness of agricultural advisory systems.

2.4 ICT and Digital Transformation of Agricultural Extension

The rapid development of ICT has created new possibilities for delivering agricultural advisory services. Mobile phones, SMS services, mobile applications, internet platforms, digital videos, social media, remote sensing, geographic information systems, sensors and other digital technologies have increasingly complemented conventional face-to-face extension.

Spielman et al. (2021), in a comprehensive review of ICT and agricultural extension in developing countries, observed that ICT-enabled extension has generated considerable interest because of its potential to improve the availability and timeliness of agricultural information. However, the evidence also indicates that ICT interventions do not automatically lead to improved technology adoption, productivity, income or welfare. Their effectiveness depends on factors such as the quality and relevance of information, accessibility, user characteristics, institutional arrangements and the interaction between digital and conventional extension mechanisms.

In the Indian context, ICT-based agricultural knowledge-sharing initiatives have expanded

through the involvement of public institutions, private organizations, NGOs and community-based organizations. Tiwari (2022) noted that ICT initiatives have been used for knowledge sharing, education, rural development and agricultural communication, while also identifying connectivity, infrastructure, content development and capacity-building as important areas requiring continued attention.

The literature therefore suggests that digital extension should not necessarily be viewed as a replacement for conventional extension. Instead, a hybrid model combining digital tools with human intermediaries and local institutions may provide more effective and inclusive advisory services.

2.5 Emerging Technologies: IoT, Precision Agriculture and Data-Based Advisory

The emergence of the Internet of Things (IoT), sensors, remote sensing, drones and data analytics has further expanded the technological scope of agricultural extension. These technologies can support more location-specific and timely information related to irrigation, soil conditions, crop health, pest and disease management and resource use.

Research on IoT applications in Indian agriculture has highlighted the potential of connected technologies to support precision agriculture and strengthen extension advisory services. At the same time, technological adoption faces challenges including inadequate infrastructure, digital literacy, affordability, data-related concerns and limited awareness among farmers. Therefore, the availability of technology alone does not guarantee effective adoption.

The broader literature on digital agriculture also indicates that artificial intelligence, IoT, remote sensing and precision agriculture are interconnected components of the emerging digital agricultural ecosystem. Their usefulness for extension depends on the ability of advisory systems to convert complex data into understandable, timely and actionable information for farmers.

2.6 Climate-Smart Agricultural Extension

Climate change has added another important dimension to the role of agricultural extension. Increasing variability in temperature, rainfall and extreme weather events has created a need for advisory services that support adaptation, efficient resource management and risk reduction.

Kumar et al. (2022) reviewed the relevance of extension advisory services in climate-smart agriculture and emphasized the importance of timely weather and climate information for agricultural decision-making. Extension services can support farmers by disseminating information on climate-resilient practices, improved crop varieties, water management, pest and disease management and other adaptation measures.

Climate-smart extension therefore represents an extension paradigm in which advisory services are expected not only to increase productivity but also to strengthen resilience and promote sustainable resource use. The integration of weather information, local knowledge and scientific recommendations can improve farmers' ability to respond to climatic uncertainty.

2.7 Farmer Producer Organizations and Market-Oriented Extension

The increasing commercialization of agriculture has also changed the objectives of extension services. Modern advisory systems increasingly address not only production-related information but also market prices, value addition, quality standards, processing, branding, finance and supply-chain linkages.

Farmer Producer Organizations (FPOs) have emerged as an important institutional mechanism for collective action among small and marginal farmers. By aggregating farmers, FPOs can facilitate collective procurement of inputs, access to technical knowledge, marketing, processing and improved bargaining power. Studies conducted in India have documented the expansion of FPOs and their increasing role in connecting farmers with markets and institutional support.

Market-oriented extension therefore expands the traditional definition of extension from "production advisory" to a broader system covering production, aggregation, value addition and marketing. However, organizational capacity, governance, finance, market access and managerial skills remain important factors influencing the effectiveness of FPOs.

2.8 Public–Private Partnerships and Extension Pluralism

The growing complexity of agricultural development has encouraged collaboration between public agencies and private organizations. Public–Private Partnerships (PPPs) can contribute financial resources, technological expertise, market linkages

and specialized knowledge, while public institutions can provide institutional reach, policy support and wider rural coverage.

Ponnusamy (2013) highlighted the role of PPPs in knowledge management, capacity building, technology development, processing and market promotion in agriculture. Sharma et al. (2020) similarly emphasized the potential of public–private partnerships in improving the efficiency and reach of agricultural extension while supplementing limited public resources.

Nevertheless, partnership-based extension requires clearly defined responsibilities, accountability and coordination mechanisms. Commercial interests must also be balanced with farmers' information needs and public-development objectives. Thus, PPPs can strengthen extension systems when appropriate institutional safeguards and coordination mechanisms are established.

2.9 Gender and Inclusiveness in Digital Extension

Inclusiveness has become an increasingly important consideration in the modernization of agricultural extension. Women farmers, smallholders, resource-poor farmers and farmers located in remote areas may face unequal access to conventional as well as digital advisory services.

Research on gender-responsive digital extension has highlighted that the introduction of digital technologies does not automatically eliminate existing gender inequalities. Access to mobile phones, internet connectivity, digital literacy, financial resources and decision-making authority can influence whether women farmers are able to benefit from digital advisory services.

Consequently, future extension systems need to consider not only technological efficiency but also accessibility, affordability, digital literacy and the social conditions affecting technology use. Gender-sensitive and inclusive extension approaches can help ensure that digital transformation does not widen existing disparities.

2.10 Research Gap

The literature demonstrates a clear transition from conventional technology-transfer extension towards participatory, pluralistic, innovation-oriented, digital, climate-smart and market-oriented systems. However, these paradigms are often discussed separately, while agricultural extension in practice increasingly requires their integration.

Digital technologies can improve the speed and scale of information delivery, but their effectiveness depends on human facilitation, farmer capabilities and institutional support. Similarly, participatory approaches can strengthen local learning and adoption, while innovation systems can connect farmers with research institutions, private organizations and markets. Climate-smart extension adds the requirement of resilience and sustainability, whereas FPOs and market-oriented approaches extend advisory services towards commercialization and collective action.

A major research requirement, therefore, is the development of integrated extension models that combine digital technologies, participatory learning, innovation-system facilitation, climate-smart advisory services, market linkages and inclusive institutional mechanisms. Such an integrated approach can potentially improve the relevance, reach and sustainability of agricultural extension, particularly for smallholder farmers in developing-country contexts.

3. Observations and Analysis

Agricultural extension plays a vital role in connecting research institutions with farmers through knowledge sharing, capacity building and advisory services. Modern extension emphasizes farmer participation, digital tools, climate resilience, market orientation, entrepreneurship, sustainability and multi-stakeholder collaboration. Emerging technologies such as AI, remote sensing, drones, IoT, mobile advisory and big data are reshaping advisory services. Despite significant progress, constraints such as digital divide, limited infrastructure, shortage of trained personnel and financial limitations remain. Agricultural extension plays a vital role in connecting research institutions with farmers through knowledge sharing, capacity building and advisory services. Modern extension emphasizes farmer participation, digital tools, climate resilience, market orientation, entrepreneurship, sustainability and multi-stakeholder collaboration. Emerging technologies such as AI, remote sensing, drones, IoT, mobile advisory and big data are reshaping advisory services. Despite significant progress, constraints such as digital divide, limited infrastructure, shortage of trained personnel and financial limitations remain.

Table 1: Evolution of Agricultural Extension Paradigms

Extension Paradigm	Period	Major Characteristics	Limitations
Technology Transfer	Before 1980	One-way communication, expert-driven recommendations	Low farmer participation
Training & Visit (T&V)	1980–1995	Regular field visits and demonstrations	High operational cost
Participatory Extension	1995–2010	Farmer participation, local knowledge integration	Time-consuming implementation
Agricultural Innovation System	2010–Present	Multi-stakeholder collaboration	Coordination challenges
Digital Extension	Present	ICT, AI, mobile advisory, remote sensing	Digital divide and connectivity issues

Table 2: Emerging Trends in Agricultural Extension

Emerging Trend	Description	Major Benefits
Digital Agriculture	Mobile apps, ICT, AI, IoT	Real-time advisory services
Climate-Smart Agriculture	Climate-resilient technologies	Better adaptation to climate change
Precision Agriculture	GPS, GIS, drones, sensors	Efficient resource utilization
Market-led Extension	Market information and value chains	Increased farmer income
Farmer Producer Organizations (FPOs)	Collective farming and marketing	Improved bargaining power
Public–Private Partnership	Government and private collaboration	Wider extension coverage
Gender-sensitive Extension	Women-focused advisory services	Inclusive agricultural development

4. Results and Discussion

The review of recent literature indicates that agricultural extension has undergone a remarkable transformation from conventional technology transfer approaches to participatory, digital, climate-smart, and market-oriented extension systems. These changing paradigms have positively influenced agricultural productivity, farmer empowerment, sustainability, and rural livelihoods.

One of the most significant findings is the increasing adoption of **Information and Communication Technologies (ICTs)** in extension services. Mobile applications, digital advisory platforms, artificial intelligence (AI), remote sensing, drones, and Internet of Things (IoT) technologies have enabled farmers to receive real-time information on weather forecasts, pest and disease management, irrigation scheduling, nutrient management, and market prices. These technologies have improved decision-making, reduced production risks, and increased farm productivity.

The review also highlights the growing importance of **participatory agricultural extension**, where farmers actively participate in identifying problems, testing technologies, and sharing knowledge. Farmer Field Schools (FFSs), Farmer Producer Organizations (FPOs), and community-based extension approaches have enhanced technology adoption, strengthened local innovation, and increased farmers' confidence in scientific recommendations.

Climate-smart agricultural extension has emerged as another major positive outcome. Extension systems now provide timely climate advisories, promote drought- and flood-tolerant crop varieties, encourage water-saving irrigation techniques, and support integrated pest management. These interventions have improved farmers' resilience to climate variability while promoting sustainable agricultural production.

The literature further reveals that **Agricultural Innovation Systems (AIS)** have strengthened collaboration among research institutions, extension agencies, private companies, NGOs, and

farmers. Such multi-stakeholder partnerships have accelerated technology dissemination, improved access to quality inputs and financial services, and created opportunities for value addition and market linkages.

Market-led extension approaches have also contributed to higher farm incomes by providing information on market prices, quality standards, processing, branding, and supply chains. The establishment of Farmer Producer Organizations has enhanced collective marketing, bargaining power, and access to institutional credit, resulting in improved profitability for smallholder farmers.

Overall, the reviewed studies demonstrate that the integration of digital technologies, participatory methods, climate-smart practices, and institutional collaboration has significantly improved the effectiveness of agricultural extension. These emerging paradigms support sustainable agricultural development, increase farmers' income, enhance food security, and contribute to achieving the Sustainable Development Goals (SDGs).

5. Conclusion

Agricultural extension plays a vital role in connecting research institutions with farmers through knowledge sharing, capacity building and advisory services. Modern extension emphasizes farmer participation, digital tools, climate resilience, market orientation, entrepreneurship, sustainability and multi-stakeholder collaboration. Emerging technologies such as AI, remote sensing, drones, IoT, mobile advisory and big data are reshaping advisory services. Despite significant progress, constraints such as digital divide, limited infrastructure, shortage of trained personnel and financial limitations remain. Agricultural extension plays a vital role in connecting research institutions with farmers through knowledge sharing, capacity building and advisory services. Modern extension emphasizes farmer participation, digital tools, climate resilience, market orientation, entrepreneurship, sustainability and multi-stakeholder collaboration. Emerging technologies such as AI, remote sensing, drones, IoT, mobile advisory and big data are reshaping advisory services. Despite significant progress, constraints such as digital divide, limited infrastructure, shortage of trained personnel and financial limitations remain.

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Observation Table

Trend	Technology	Impact	Challenge
Digital Extension	Apps/ICT	Fast advisory	Digital literacy
AI	Machine learning	Decision support	Data quality
CSA	Weather tools	Resilience	Adoption
FPOs	Collective action	Market access	Governance
PPP	Public-Private	Resource sharing	Coordination

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