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Agricultural Extension Education: Bridging Knowledge, Technology, and Market Demands for a Sustainable Future

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Introduction

Agricultural extension education has traditionally acted as an essential link between knowledge and rural communities, going beyond the scope of formal educational institutions. As defined by Reddy (1993), extension education is a science focused on creating, transmitting, and applying knowledge to instigate planned behavioural changes among individuals. This process helps individuals improve their livelihoods through an enhanced understanding of agricultural practices, vocations and institutions.

In India, the extension system is categorized into two main components: Extension Education and Extension Training. Research and Education (R&E) encompasses extension education, while Extension and Training involves frontline and field-level extension activities (Nandi and Nedumaran, 2019). Effective extension programs rely on five essential and interrelated steps: assessing the current situation, setting objectives, teaching methodologies, evaluating outcomes, and reflecting on future actions. According to Kelsey and Hearne (1967), the basic philosophy of extension education is "to teach people how to think, not what to think".

Historical Context of Extension Education in India

The evolution of extension education in India has undergone significant transformations over time. During the pre-independence era, notable initiatives, such as Rabindra Nath Tagore's Sriniketan Project (1920) and the Firka Development Scheme (1946), laid foundational work for rural welfare. Early post-independence, the government launched several key programmes aimed at agricultural development, including the Etowah Pilot Project (1947), the Key Village Scheme (1952), and the Community Development Block (1954).

The establishment of the Integrated Agricultural Development Programme (IADP) in 1960 marked a turning point, followed by initiatives like the High Yielding Variety Programme (HYVP) in 1966 and the National Agricultural Technology Project (1998). The advent of Krishi Vigyan Kendras (KVKs) and Agriculture Technology Management Agencies (ATMA) at the district level further revolutionized the extension delivery system in India. Both these wings became integral to the National Agricultural Research System (NARS), performing a wide range of activities but focusing mainly on technology assessment, demonstrations/ frontline demonstrations, and capacity building, although differences between the two setups exist.

Players involved in Extension Delivery:

At the central level, the Indian Council of Agricultural Research (ICAR) stands as the premier institute guiding agricultural research and extension efforts. At the state level, State Agricultural Universities (SAUs) assume a vital role, complemented and supplemented by the work of KVKs at the district level. The agriculture and other allied development departments of each state, both directly and through ATMA at the district level, play an active role in promoting agricultural extension. KVK functions as frontline research - extension linkage, whereas ATMA as a field extension agency works for large-scale technology dissemination/adoption, up-scaling of successful technologies/innovations through large-scale demonstrations and further verification/validation, etc. (Natarajan Ananth *et al.*, 2019). In addition to the services of KVK and ATMA, many times SAUs and their affiliated colleges also participate directly in extension activities enriching the agricultural landscape. Many private players like input dealers, chemical or fertilizer companies or suppliers, and social or non-governmental organizations are also involved in extension delivery mechanisms.

Current Challenges in Extension Delivery

Despite the advancements, the extension delivery system still faces significant challenges. Throughout the globe, extension agencies face challenges from both finances and manpower. The whole country is grappling with a significant shortage of extension officers at various levels. Out of 143,863 positions in the Department of Agriculture, only 91,288 are filled (Gulati *et al.*, 2018).

This substantial gap in the workforce means that, on average, extension services reach merely 6.8% of farmers (FAO, 2012). The current ratio of extension workers to farmers is alarmingly low at 1:1162, compared to the recommended national standard of 1:750 (Mishra *et al*., 2022). This imbalance severely limits the effectiveness of outreach efforts. Furthermore, over the years, the understaffed extension departments have been burdened with non-extension works (Nandi and Nedumaran, 2019). This gap has prompted the emergence of private extension services. There are several private players like civil society organizations including farmer-based organizations and NGOs that play a major role in providing extension services (Birner and Anderson, 2007). However, the profit-driven motives of private organizations often lead to inadequate support for most rural farmers. One study estimated that 13% of farmers get their information from input dealers in the country (Singh *et al*., 2016). However, a major complaint against input dealers is that they are involved in product promotion instead of technical advice to the farmers (Nandi and Nedumaran, 2019).

In response, extension workers have adopted a group approach, promoting community-based organizations such as Self-Help Groups (SHGs), Farmers' Interest Groups (FIGs), Farmer Producer Organizations (FPOs) etc. to cover large masses with less effort. Nevertheless, a persistent disconnect remains between research and practical application in the field. To bridge this gap, extension professionals are increasingly leveraging e-extension methods, utilizing digital tools such as web portals, mobile applications and social media platforms. Cyber extension harnesses information and communication technology (ICT) to enhance information accessibility for farmers and extension workers (Mondal, 2019), promoting a more inclusive and responsive agricultural extension system.

The Shift towards Market-Responsive Extension

Agricultural extension started from basic education during post-independence to Green Revolution technologies, then to sustainability moving towards participatory methods (post-Green Revolution era). The focus shifted towards the integration of digital tools, climate-smart or climate-resilient practices, and market linkages in the recent past to meet farmers' emerging needs and to ensure rural development. The contemporary landscape of agricultural extension is evolving into a market-based approach, emphasizing technologies and practices that align with consumer demands for diverse, nutritious, and safe food. This transformation reflects a significant shift from a production-centric supply chain to a demand-responsive value chain, prioritizing adoption and upscaling of product-oriented technologies.

In recent years, the shrinking of agricultural land - evidenced by a decrease of 1.6 million hectares from 2001-02 to 2010-11 (Govindaprasad and Manikandan, 2016) - has intensified the challenges surrounding food security. Studies reveal that the conversion of farmland results in an annual loss of 1.07 tons of output per acre, a situation further exacerbated by a growing population. In this context, high-tech agricultural solutions such as precision farming and vertical farming, both in agriculture and allied sectors, are becoming increasingly vital.

To address the escalating diversified and safe food demand and shifting consumer preferences from cereal-based products to high-value produce, particularly in urban areas, agricultural production systems must adapt accordingly (Birthal *et al*., 2015). Furthermore, urban agriculture is gaining importance, driven by the urgent need for health and/ or nutritional security rather than the production-oriented goal within urban environments.

Modern agriculture is characterized by technology-driven practices that rely less on human labour, favouring mechanization and efficient resource utilization. This shift not only enhances productivity but also promotes climate-resilient farming techniques, paving the way for a more sustainable future in food production.

The Future of Agricultural Extension

Looking ahead, the future of agricultural extension will heavily integrate artificial intelligence (AI) and other advanced technologies. Already different electronic media, and social media platforms are being used for information and technology dissemination to the target groups. The successful use of AI has been described for predicting weather (Sing and Kaur, 2022), predicting disease or pest infestation in crops (Klerkx *et al*., 2019), detecting soil defects by studying soil nutrient status (Tang *et al*., 2018; Vangala *et al*., 2020), water management practices (Zhang *et al*., 2020), the clinical status of animals like measuring body temperature (Chung *et al*., 2020), heart rate (Zipp *et al*., 2018), respiration rate (Stewart *et al*., 2017), body measurement in small animals (Zhang *et al*., 2018), grazing behaviour of animals (Giovanetti *et al*., 2017), supply of vaccines in human from distribution centre to health centre through drone (Ansari *et al*., 2025) etc. AI-based solutions are emerging as effective tools for reaching larger populations with minimal workforce involvement, although many AI developments such as drone applications, sensor technologies, and machine learning are still primarily academic or in limited use. In the coming years, these innovations, in more refined forms, are expected to enhance the efficiency and effectiveness of extension services ensuring even underserved farmers receive essential support.

As extension systems progress, they must be tailored to the specific needs of target groups, aligning with the rapid changes in agricultural practices and market demands. The emphasis will shift towards providing customized, technology-driven solutions that empower farmers to make concrete decisions.

Conclusion

The shift in agricultural extension education reflects broader societal, technological, and consumer changes, with challenges like workforce shortages and the research-practice gap. Advanced technologies, such as AI and digital tools, offer promising solutions. To ensure food security and improve rural livelihoods, strong collaboration among farmers, extension workers, technology developers, and other stakeholders is essential. By embracing climate-resilient, community-focused practices, market-responsive extension services will boost productivity, sustainability, and resilience, ultimately fostering a more prosperous and inclusive rural economy

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