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RESEARCH ARTICLE

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# Levelling the field: A review of the ICT revolution and agricultural extension in the Global South

Rashid Parvez Khan[1] | Saurabh Gupta[2] | Thomas Daum[1] | Regina Birner[1] | Claudia Ringler[3]

[1]Hans-Ruthenberg-Institute of Agricultural Science in the Tropics, University of Hohenheim, Stuttgart, Germany

[2]Centre for Development Policy and Management (CDPM), Indian Institute of Management, Udaipur, India

[3]Natural Resources and Resilience Unit, International Food Policy Research Institute, Washington, DC, USA

**Correspondence**
Rashid Parvez Khan, Hans-Ruthenberg-Institute of Agricultural Science in the Tropics, University of Hohenheim, Wollgrasweg 43, 70599, Stuttgart, Germany.
Email: rkhan.p@gmail.com

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## Abstract

Information and communications technology has evolved significantly over the last seven decades, beginning with radio and video vans and culminating in the rise of smartphones and mobile internet in remote areas of the Global South. While ICT is an integral part of agricultural extension, little is known about how these changes have influenced agricultural extension practices. After a systematic review of 131 papers, we find that changes in ICT have shaped agricultural extension, enabling a shift from linear dissemination and "one-way communication" to co-innovation and farmer-to-farmer learning. The results indicate the potential for smartphones and mobile internet to democratize agricultural extension.

**KEYWORDS**
agricultural extension, developing countries, information and communications technology (ICT), mobile internet, smartphone, video

## 1 | INTRODUCTION

Agricultural extension is key to improving rural livelihoods by providing information on improved agricultural practices, supply of inputs, access to markets and weather forecasting, among others. There is no set definition of extension, but it is widely acknowledged that it refers to communication that helps people make decisions (Black, 2000). The extension covers both technical knowledge and the elements of communication, facilitation and empowerment

(Davis et al., 2018). Agriculture extension is defined as 'a system which assists a farm through educational procedures, in improving farming methods and techniques, increasing production efficiency and income, bettering their levels of living and lifting the social and educational standards of rural life' (Maunder, 1972, p. 3). Agricultural extension has evolved over nearly 4,000 years (Allanson, 1988; Jones & Garforth, 1994). The first known example of "traditional" information dissemination tool is clay tablets bearing inscribed instructions on watering crops to address a rat problem in Mesopotamia (Ahmed, 1982). Similarly, the Han Dynasty in Imperial China (25–220 AD) used agricultural information services. During the Sung and Yuan dynasties (960–1,368), the invention of woodblock printing facilitated the promotion of agricultural extension through practical handbooks (Jones & Garforth, 1994). In Europe, agricultural extension can be traced back to the Renaissance, but the birth of modern agricultural extension took place only in the 19th century (Boon, 2010; Ponniah et al., 2008; Swanson et al., 1997).[1] Over time, work on extension has matured and broadened, especially in the Global North. With the onset of decolonization in the Global South following the end of World War II, the scope of agricultural extension also expanded in many low- and middle-income countries (LMICs). Hence, it is particularly interesting to study extension practices over the last seven decades from the perspective of the Global South (Anderson & Feder, 2007).

A defining feature of agricultural extension has been its constant renewal in tandem with advances in information and communications technology (hereafter ICT). Agricultural information systems have evolved significantly over the last seven decades, starting with tools such as newspaper and radio, expanding to television and video, and more recently, cell phones, smartphones and mobile internet. There is a growing interest among rural development agencies and professionals to understand the role of ICT in shaping and enhancing agricultural extension. This is especially true as agriculture faces the challenges of growing climate uncertainties, continued gender inequalities and recurrent agrarian crises in developing countries. Traditional ICT such as newspapers, radio and television, which were popular until the end of the last century, were largely limited to the one-way transfer of information and were therefore plagued by information asymmetry (Fu & Akter, 2016; Islam & Grönlund, 2011). As such, traditional ICT struggled to meet the farmers' information needs and to deliver timely, accurate and customized information (Gao et al., 2020; R. Singh et al., 2023).

ICT has advanced dramatically since the beginning of the 21st century, particularly as mobile phone subscriptions increased (Nakasone et al., 2014). Arguably, modern ICT can help in improving the performance of agricultural extension (Duncombe, 2016; Nakasone & Torero, 2016). Cell phones and smartphones promise to support farmers with timely and location-specific information and help in the adoption of more knowledge-intensive production and marketing practices (Emeana et al., 2020; Karanasios & Slavova, 2019; N. Khan et al., 2020; Mbuyisa & Leonard, 2017). With farmers able to request information, cell- and smartphones have also demonstrated their suitability in addressing information asymmetries (Ali & Kumar, 2011; de Silva et al., 2009; Fafchamps & Minten, 2012; Gandhi et al., 2007; Mittal & Mehar, 2012; Muto & Yamano, 2009). In advanced economies, these tools have become a part of life for many farmers, helping to democratize the generation and dissemination of agriculture information. Democratization of agricultural extension can be understood as an information exchange among farmers by sharing their own photos, text messages, voice recordings or videos on issues relating to agriculture through smartphones and social media platforms. As the penetration of smartphones and affordable mobile internet is increasing rapidly in the rural areas of the Global South, it is worth examining the potential of modern ICT tools in democratizing messaging in agricultural extension, the main focus of this review paper.

This paper examines the evolution of ICT over the last seven decades, that is in different phases of agrarian change, and explores how this affected agricultural extension based on an extensive review of the literature. Reviewing how historical changes in ICT have shaped agricultural extension, and assessing how effective technology has been in meeting farmers' extension demands over time allows us to better understand and contextualize the potential and challenges of modern ICT in providing agricultural information. This will also help in evaluating if and how the latest ICT tools can cater to the farmers' information needs vis-à-vis the grand challenges of the 21st century, including but not restricted to addressing climate change and reaching out to women farmers (Issahaku et al., 2018). With the help of the following guiding questions, we conduct the review:

- How has the ICT for agricultural extension evolved and changed over time?
- What have been the advantages and challenges of different types of ICT tools in disseminating agricultural information to farmers? To what extent has the changing nature of ICT led to the democratization of messaging for agricultural extension?

The paper is structured as follows: Section 2 introduces a conceptual framework that uses a historical perspective to explain the changing nature of ICT for agricultural extension, while Section 3 presents the methodology used for the review. Sections 4 and 5 present the results of a review of the literature on ICT for agricultural extension, focusing on the origins and changing nature of extension services. The discussion in section 6 focuses on the latest innovations in agricultural information systems and the concluding section summarizes the key findings from the review.

## 2 | CONCEPTUAL FRAMEWORK

The literature review is guided by a conceptual framework (Figure 1). The authors adopt a historical perspective in evaluating the capability of the dominant ICT tools corresponding to the different phases of agricultural extension services and explain the changing nature of agricultural extension from the 1950s to the present times. The framework shows three parallel streams, which – as we will show – greatly influence each other: the dominant extension paradigm, the types of agriculture practices and the main ICT tools and their capabilities.

In the 1950s and 1960s, agriculture extension practices were restricted to one-way, top-down information dissemination from researchers and governments to farmers mainly engaged in subsistence agriculture (Boon, 2010; Jones, 1986). This paradigm is referred to as "transfer of technology" (Anderson et al., 2006; Cook et al., 2021; Picciotto & Anderson, 1997). In the 1960s, many developing countries such as India witnessed massive food crises, which triggered the Green Revolution that aimed to intensify agriculture and achieve food self-sufficiency using high-yielding varieties of seeds, chemical fertilizers, pesticides and secured irrigation (Umali-Deininger, 1997).

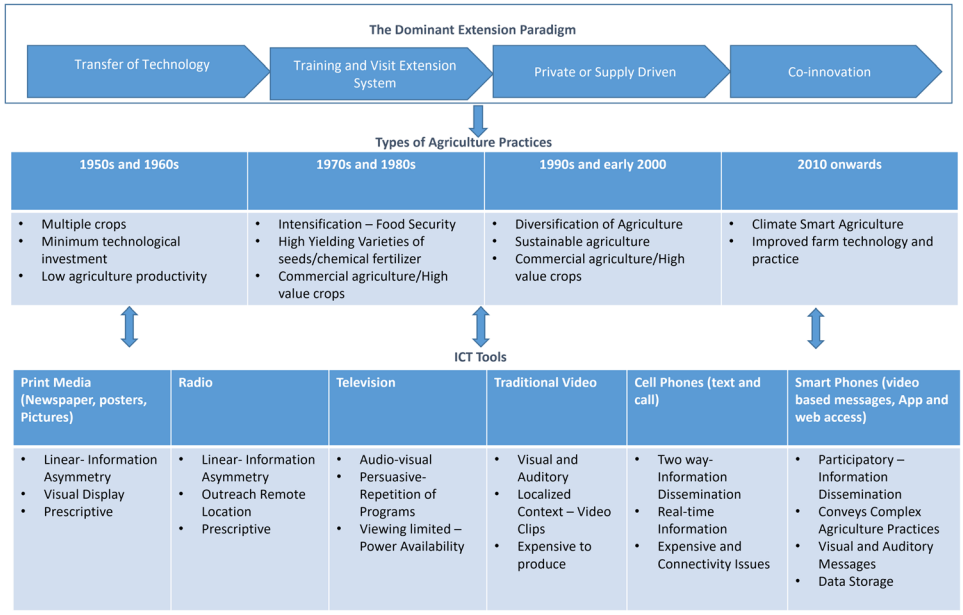


**FIGURE 1** ICT and agricultural extension. Source: Authors' own compilation.

Adoption of these agricultural technology-based practices required advanced skills and knowledge and the messaging remained one-way and top-down (Briones & Felipe, 2013). During the 1970s and 1980s, information dissemination on agricultural practices increased in complexity, necessitating new approaches for an extension, exemplified in the "training and visit" extension system where extension agents demonstrate the use of these technologies through weekly visits. However, the information flow remained supply-driven (Ferroni & Zhou, 2012). In the 1990s and early 2000s, due to the growing commercialization of agriculture, where farms increasingly specialized in fewer commodities and growing shares of farm products were sold, private players also started to provide extension services, mainly to large, sales-oriented farmers in specific regions. Extension systems lacked participation and accessibility, and as in previous decades, largely remained top-down (Westermann et al., 2015).

Over the last decade or so, co-innovation and participatory forms of extension systems have become more common. The co-innovation form of the extension system is a part of the agricultural knowledge and innovation system (AKIS), which includes different stakeholders, i.e., public extension providers, private agencies, NGOs, farmer groups, cooperatives and farmers (Botha et al., 2017). These stakeholders are involved in all steps, from the co-design phase of developing extension practices to the final delivery of the information to the farmers (Friederichsen et al., 2013). AKIS puts emphasis not only on actors but the influence of institutions and infrastructure that include organizations beyond extension systems and agricultural research. All the actors play an important role in the innovation processes by innovating, changing and learning (Klerkx et al., 2012). Of all the actors, farmers' local knowledge and its integration with modern agriculture practices is central in bridging the gap between traditional knowledge systems and modern agriculture practices (Klerkx et al., 2016; Roberts et al., 2023; Utter et al., 2021). Farmers share local knowledge to improve agriculture practices and techniques. It is an iterative process where farmers collaborate with other stakeholders to support changes in farming practices and adopt new technology for improving productivity (Laurens et al., 2023).

These phases of agricultural extension approaches were accompanied by parallel changes in ICT. Earlier forms of ICT such as newspapers and radio were used to convey generic agricultural information on crop husbandry practices as well as price developments and weather forecasts (Aker, 2011). A technological shift in ICT use led to the emergence of television and video demonstrations, which enabled to convey more complex messages to farmers. It complemented the need for such messages due to changes in farming with the rise of the Green Revolution. However, with such ICT, information provision remained supply-driven and one-way. Television and video vans for demonstration lacked feedback loops necessary for two-way communication between the agents and farmers. The arrival of cellular phones at the turn of the 21st century and the emergence of smartphone usage over the last few years has created new possibilities for addressing the imperfect information flows between farmers, researchers, extension agents, traders and scientists (Steinke et al., 2020). With the advent of smartphones and affordable internet services, the potential for two-way communication between farmers and researchers has increased (Ballantyne, 2009). Farmers can now watch videos on new agriculture practices on social media platforms like YouTube and share text, pictures, videos and audio files with fellow farmers through WhatsApp Messenger, supporting farmer-to-farmer communication with large groups of farmers facing similar challenges (Kumar, 2023). Farmers can thus communicate with their peers and extension agents instantly and receive real-time feedback on the challenges they experience (Gayatri & Arunachalam, 2016; Singh Nain et al., 2019). The ability of new ICT such as smartphones and the use of social media apps like WhatsApp, YouTube and Facebook might thus support the democratization of agricultural extension. The following section presents the methodology adopted for the review of the literature on which this paper is based.

## 3 | RESEARCH METHODOLOGY

The conceptual framework (see Figure 1) helped us identify and classify the literature based on references to the evolution of agricultural extension and ICT over the last seven decades. The literature was reviewed between

02 August 2020 and June 2024 using Wiley Online, Taylor and Francis, Springer collection, Science Direct, Emerald, JSTOR, ProQuest, Sage Collection, World Bank e-library and AGRIS databases. The study focused on papers published from 1950 (available in Scopus from 1959) to June 2024.

## 3.1 | Search strategy

The keywords used for the search are as follows: ("*agriculture* extension*") AND ("*ICT agriculture* extension*") AND (*"radio agriculture* extension"*) AND (*"TV* OR *Television agriculture* extension"*) AND (*"video agriculture* extension"*) AND (*"mobile* OR *cell* OR *phone* OR *smartphone agriculture extension"*) AND (*"social media agriculture* extension"*). These keywords were used for searching in the Scopus database. The search produced 686 studies. The search was further expanded to databases such as Wiley Online, Taylor and Francis, Science Direct and Sage Collection, which yielded 459 articles. We also explored other databases such as the World Bank e-library, AGRIS, CGIAR, CABI, IDEAS, IEEE Xplore and IFPRI database, which yielded 22 more articles which formed a cumulative of 1,167 articles.

## 3.2 | Study selection criteria

Inclusion and exclusion criteria are listed in Table 1. In addition to the study period and the topic at hand, papers had to be available in English and focus on four key LMIC regions: South Asia, Southeast Asia, Sub-Saharan Africa, Latin America and the Caribbean. The original 1,145 studies were reduced to 398 studies by applying the full set of inclusion and exclusion criteria. They were then reduced to 131 studies after excluding studies that did not actually refer to the evolution of ICT for agricultural extension, its potential and limitations and the use of modern ICT in addressing the complex agricultural practices of current times (see Table 2).

**TABLE 1** Inclusion and exclusion criteria.

| | |
|---|---|
| **Inclusion criteria (IC)** | |
| IC1 | Papers published between 1950 and 2024 |
| IC2 | Papers related to agricultural extension and ICT and agricultural extension |
| IC3 | Papers that cover South Asia, Southeast Asia, Latin America, the Caribbean and the Sub-Saharan Africa region |
| **Exclusion criteria (EC)** | |
| EC1 | Duplicate publications from multiple sources |
| EC2 | Papers without full text that cannot be accessed from databases |

**TABLE 2** Overview of the literature search result.

| Source | Retrieved | Included | Selected |
|---|---|---|---|
| Scopus | 686 | 167 | 68 |
| Wiley Online | 30 | 14 | 9 |
| Taylor and Francis | 140 | 76 | 17 |
| Science Direct | 230 | 84 | 12 |
| Sage | 59 | 57 | 4 |
| Others[a] | | | 22 |
| **Total** | **1,145** | **398** | **131** |

[a]World Bank e-library, AGRIS, CGIAR, CABI, IDEAS, IEEE Xplore, IFPRI database.

A coding scheme was applied to code all 131 articles. Articles were coded to identify the historical evolution and agricultural practices during the 1950s and 1960s, the 1970s and 1980s, the 1990s and 2000s and the 2010s to the present time. We also coded articles that focused on ICT and agricultural extension to identify the use of ICT, including the capability and limitations of the technology in the different periods. We also coded the use of innovative ICT such as video-based messaging, mobile phone usage and their capability to communicate complex agricultural practices. Innovative ICT refers to communicating extension messages to farmers with no or limited literacy and conveying technical information simply through voice, or video messages. This methodology allowed us to map the historical evolution of extension and the changing nature of ICT and to assess how effective technology has been in meeting farmers' extension demands. It also allowed us to assess the capability of modern ICT (mobile internet, smartphones, social media apps) in communicating information related to complex agricultural practices such as climate-smart agriculture and ecologically sustainable agriculture. These 131 articles were used to develop the key themes described in Figure 1 and are analysed in greater depth in the following sections. The next section describes the history of agricultural extension.

## 4 | EVOLUTION OF AGRICULTURAL EXTENSION IN DEVELOPING COUNTRIES

The evolution of agricultural extension in developing countries can be summarized under different phases: a) agriculture extension as technology transfer in the 1950s and 1960s; b) the training and visit system in the 1970s and 1980s; c) private and supply-driven system in the 1990s and early 2000s; d) co-innovation extension system in the recent times.

Agricultural extension as technology transfer (1950s and 60s).

After independence, most developing countries followed the 'statist model' of development, where the government controlled all sectors, including agriculture and the extension system through centralized, state-owned institutions (Carney, 1998). Top-down planning and information provision resulted in a linear and prescriptive process with farmers at the end of the information chain and no possibility of feedback (Birner & Anderson, 2007; Cook et al., 2021; Ragasa et al., 2013). In many developing countries, commodity-oriented technical guidance was provided during colonial times to farmers producing commercial crops, but national agricultural advisory services were not formally established until the 1950s and 1960s (Anderson, 2008). Newly independent countries in Asia and Africa, and some in Latin America focused on increasing national food production through advanced farming practices (Da Ros, 2012; Kaimowitz, 1993). High-yielding varieties of food crops, fertilizers, pesticides and irrigation systems were introduced in the late 1960s to achieve food security and self-sufficiency, particularly in Asia. Agricultural technology packages were complemented by government support to expand farming system coverage (Landini, 2015; Pineiro & Trigo, 2019; Ros, 2012a; Wu & Butz, 2004). The extension coverage focused on transferring technology from researchers to adopters. However, farmers and researchers later criticized the technology transfer model because it was linear and not effective for resource-poor farmers (Anderson, 2008; Boon, 2010).

### 4.1 | Training and visit extension system (1970s and 80s)

Like the agriculture practices in the 1950s and 1960s, the Training and Visit' (T&V) system sponsored by the World Bank in the 1970s and 80s focused on yield improvement and increasing food production (Benor & Harrison, 1977). During both periods, agriculture inputs and improved agriculture practices played an important role. In the T&V extension system, extension agents trained contact farmers, typically progressive large-scale farmers (Cernea, 1981; Hussain et al., 1994), who were expected to adopt new agricultural practices themselves and disseminate them among other farmers in the village (Feder et al., 1986). However, identifying the appropriate contact farmers was difficult (Moore, 1984). Many were affluent, educated, well-connected and male and there were few female contact farmers

and extension agents (Benor et al., 1984; Mundial, 1982; Taylor & Bhasme, 2018). Other challenges included weak direct linkages with farmers (Birner & Anderson, 2007). For example, extension messages given to contact farmers were often not communicated to farmers in the neighbouring villages (Lühe, 1991). As a supply-driven system, approaches promoted by T&V were developed by research scientists with a few inputs from farmers (Ferroni & Zhou, 2012). Moreover, insufficient attention was paid to input availability, which often limited the relevance of the information provided to farmers (Anderson, 2006). Due to the limitations of the T&V system, the 'Farming Systems Approach to Research and Extension (FSR-E)' emerged in the early 1980s. This approach was more participatory, involving the participation of farmers, utilization of local resources and use of traditional knowledge.[2] However, the debt crisis and a neo-liberal consensus on "rolling back the state" led to underfinancing of public extension, staffing shortages and the contraction of extension services in many countries across Asia, Africa and Latin America (Amanor & Farrington, 1991).

## 4.2 | Pluralistic extension system (from the 1990s onwards)

The failure of the T&V extension system and the contraction of public extension led to the emergence of pluralistic extensions with multiple actors. Pluralistic extension combined extension services from the public Ministries of Agriculture and Rural Development, private companies and NGOs. The government, private firms and donors financed the extension system which lessened the T&V system's financial burden (Swanson & Rajalahti, 2010). In contrast to the supply-driven transfer of the technology model, the pluralistic extension system was broad-based and demand-driven (Buehren et al., 2019). It was a two-way information delivery system, where the farmers determined their needs, which were either provided by public, private, NGO or farmer-based organizations (Da Ros, 2012; Norton & Alwang, 2020). However, the entry of private actors like agribusiness firms, educated elites and people from the industrial sector led to a focus on profitable, high-value farming systems where farmers could pay for the services (Babu et al., 2016; Zhou 2016). Though relatively good for higher-value crops/commercial crops, it restricted the flow of information and increased social disparity (Singh & Narain, 2016). Private actors focused on large farmers having large areas (Rohit et al., 2017). For example, in India, private players focused on particular regions and commercial crops, where maximum profit could be earned (Benson & Jafry, 2013). Farmers who focused more on subsistence agriculture and those farming in less favoured areas received little support and less attention for improving their condition (Saito & Weidemann, 1990). Farmers access also depended on gender, caste and political alignment (Meera et al., 2004; Treinen & Van Der Elstraeten, 2017). Another challenge to the pluralistic system was to form a mix of extension services that could address local agriculture issues (Ferroni & Zhou, 2012).

## 4.3 | Co-innovation – innovative, participatory and engaging (2000s to the present)

The drawbacks of the T&V system include a lack of in-depth engagement with farmers because village agents did not follow a regular visit schedule. The village agents preferred interacting with large-scale farmers and the frequent trainings that were organized were expensive (Anderson, 2006). To address this problem, further change in extension approaches became apparent during the 2000s, with greater emphasis on participatory aspects and pluralism of approaches (Botha et al., 2017; Ganpat et al., 2010; Gow et al., 2020; Klerkx et al., 2016; Paschen et al., 2021). Agricultural practices promoted under the co-innovation extension system include both traditional and modern farming practices (Dogliotti et al., 2014). Co-innovation is an approach where the researcher works with stakeholders, policymakers and end-users to co-create or develop solutions.[3] It requires understanding traditional knowledge systems and embracing new knowledge (Roberts et al., 2023). Farmers are engaged from the start to the end of the co-creation of the agricultural practice. Unlike the other systems discussed above, this system is more "demand-driven" (Chipeta, 2006), with a focus on group-based learning and farmer empowerment. Earlier forms of extension lacked the resources required to adequately address the diversity of farmers' needs through conventional

extension approaches (Ballantyne, 2009; Steinke et al., 2020). The co-innovation extension system benefits from integrating analogue and digital communication channels (Birner & Anderson, 2007; Rasheed, 2012). In summary, the agriculture extension system has witnessed a rapid change from prescriptive to more participatory forms of extension services. The extension system has evolved from being supply-driven to demand-driven, where farmers work along with researchers to address issues in agriculture. In the next section, we review the parallel changes in the development of ICT for addressing the extension needs of the farmers.

## 5 | EVOLUTION OF ICT FOR AGRICULTURAL EXTENSION

Development in agricultural extension approaches has been accompanied by changes in information and communications methods and channels. The following sections describe the use of these tools during the different phases of agricultural extension.

### 5.1 | Newspaper and radio

Traditional ICT like newspapers and radio served as the primary sources of information for farmers during the 1950s and 1960s. However, newspapers were primarily concentrated in urban areas, had limited outreach, and were inaccessible to the illiterate population in most LMICs (Aker, 2011; Rehman et al., 2011). Extension services used printed materials such as newsletters, leaflets, brochures and pictures to disseminate agricultural information (Manda, 2002). Even if pictorial messages were seen as effective in communicating with illiterate populations, they had limited reach and accessibility (Abdulrahimzai, 2011). In comparison, radio had wider accessibility. One of the earliest uses of radio for agricultural information was the Farm Radio Forum, which started in Canada in 1941 and was introduced in India in 1956 and in Ghana in 1964 (Nwaerondu & Thompson, 1987). Radio was an essential mechanism for disseminating knowledge and information in different languages and formats, especially to the poor and illiterate (Arunachalam, 2004; Girard, 2003; Hudson et al., 2017; Iiboudo, 2003).

The Farm Radio Forum was structured as a listeners group, where members got together in one other's homes, to listen to and discuss the radio broadcast (Neurath, 1962). The forum members were supported with illustrated material and a discussion guide by the radio station in advance that would aid them in understanding the extension message. Each forum had 20 members who met twice a week and listened to a 30-minute program (Māthura & Neurath, 1959; Neurath, 1960). Neurath (1962) found that forum members learned much more than non-forum members. Similar studies conducted in Benin and Ghana showed that radio clubs were an effective instrument in informing and educating farmers (Abell, 1968; Anyanwu, 1978). However, such radio experiments largely catered to male farmers and did not accommodate the demands and schedules of women farmers. Moreover, while radio had a massive reach across rural areas, its monologic way of information delivery means that it could only provide a limited range of information and be used for one-way communication (Agwu et al., 2008; Chapman et al., 2003; Opara, 2008). Poor reception quality, inadequate area coverage and inappropriate broadcast time were some other drawbacks of radio (Ozowa, 1995). Although print media and radio continued as primary information service providers, it was then complemented by television and video-based information dissemination.

### 5.2 | Television and video demonstration

Information dissemination through television and video demonstrations enables the combination of sight, sound and motion. Television was considered to be more effective than print media and radio in helping farmers learn and understand agricultural practices and in transferring new agriculture technology to them (M. Ahmad et al., 2007;

Behrens & Evans, 1984). The first television-based program for farmers in India was *Krishi Darshan* (agricultural program), which premiered in 1967 at the national level. Although limited in reach as it was initially broadcasted to about 80 villages around the national capital Delhi, it was hailed as a successful program (Malhan, 1977). With the satellite instructional television experiment (SITE) launched in India in 1975, many educational and informative programs were telecasted. However, the usage of television depended upon power availability and with limited rural electrification, the usefulness of television in rural areas was limited (Feder et al., 2001). Television sets can also be operated by battery sets, but not all farmers can own them. Another method of reaching farmers was the use of video-based agricultural extension. This was popularly known as participatory video, a method in which a group of people move ahead in an iterative series of filming and reviewing to create film descriptions that convey what the people who take part in the progression really desire to say, in a way they believe is ideal (Barakabitze et al., 2017; Khatun et al., 2018; Kindon, 2003). Video-based information dissemination coalesced scattered information into a systematic and comprehensive format with a localized context and provided visual and auditory stimuli (Afroz et al., 2015; Bharti et al., 2013; Carrier & Pashler, 1992; Snyder et al., 2019). It could be disseminated using television and mobile projectors, which could be moved from one village to another (Koehnen, 2011). In India, mobile vans fitted with video screens moved from village to village showing films on the use of agriculture inputs and stopping in between to discuss and share experiences with farmers (Gulati et al., 2018). Videos were considered suitable for low-literate populations as they combined visual and verbal communication (Afroz et al., 2015; Karubanga et al., 2017; Van Mele et al., 2010; Wyche & Steinfield, 2016). However, video-based information dissemination faced production costs and infrastructural issues that limited its reach to those who owned or had access to video-viewing equipment (Bentley et al., 2019).

## 5.3 | Cellular phone and smartphone

Until the 1990s, landline phones were the main form of communication in rural areas. However, accessibility and affordability were the primary concerns (Nakasone et al., 2014). Therefore, farmers received information through newspapers, radio or television. In principle, farmers could also communicate with extension agents in face-to-face meetings, but considering the low farmer-to-extension agent ratios in most LMICs during this period, these possibilities were limited (Swanson et al., 1989). The 1990s witnessed the evolution of cellular technology (see also Figure 2), leading to mobile phones enabled with text messaging, frequency-modulated (FM) radio and web-based

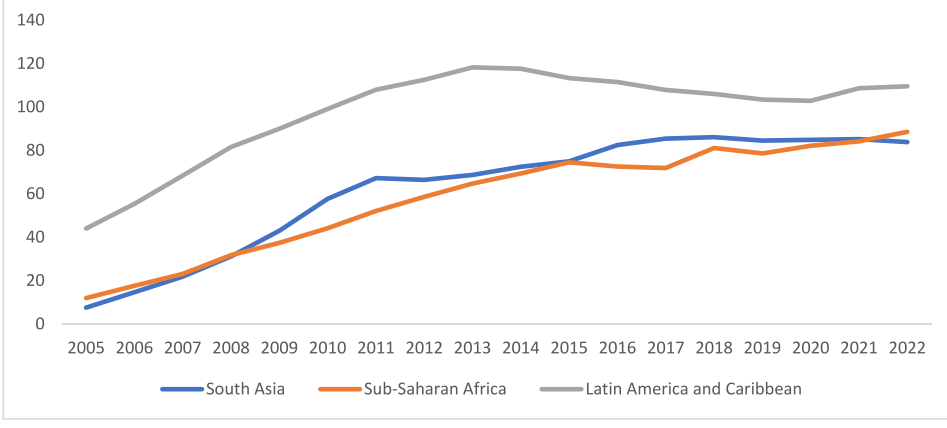


**FIGURE 2** Mobile cellular subscriptions in South Asia, Sub-Saharan Africa, Latin America and the Caribbean (per 100 people). Source: https://data.worldbank.org/indicator/IT.CEL.SETS.P2?end=2022&start=2005.

portals and applications. Cell phones facilitate two-way communication, wherein farmers can ask questions and request information. Since then, the short messaging service (SMS) of cell phones has been a key tool in providing information to farmers (Chhachhar & Md Salleh Hassan, 2012; Galeon et al., 2019; Karanja et al., 2020; Wyche & Steinfield, 2016). Another feature employed extensively was the interactive voice response (IVR), a service that used voice mail for information delivery, allowing illiterate people to participate (Baumüller, 2018; Islam & Grönlund, 2011). For example, in Kenya, the Kenya Agricultural Commodity Exchange (KACE) collaborated with Interactive Media Services Limited to provide market information through IVR (Gakuru et al., 2009), leading to reduced transaction costs and broadened trade networks among farmers (Donovan, 2017; Goyal & González-Velosa, 2013; Mundial, 2006). Similarly, the Rural Agriculture Development Authority in Jamaica uses both text and voice messages to disseminate technical information on potato production and hurricane preparedness (Williams, 2013).

Along with the use of mobile-based agricultural extension, web-based applications and portal services have also become important in sharing and disseminating agricultural information and knowledge and marketing of goods and services (Narmilan, 2017). In India, 'almost All Questions Answered' (aAQUA) is an advisory tool developed by the Developmental Informatics Lab at IIT Bombay, which integrates multiple databases into one place from where farmers can access relevant information. Similarly, the Agricultural Research and Extension Network (ARENET) project in Uganda uses a web-based platform to provide information services to small-scale farmers (Rudgard et al., 2011).

Mobile applications in agriculture (sometimes referred to as "mAgriculture") have been developed to deliver agriculture-related information. The benefits of "mAgriculture" extend potentially to all aspects of extension, service delivery and market links (Baumüller, 2022; Bazlur Rashid et al., 2009; Ferroni & Zhou, 2012). For example, in Bangladesh, *Krishok Bondhu Phone Sheba* was launched in 2018, through which any registered farmer could call and avail of extension services. Another extension service named *Banglalink* (GSM cellular mobile operator) was running an IVR-based service, *Banglalink Krishi bazaar*, which empowered producers with critical market information and eliminated middlemen (Baumüller, 2018; Chowhan & Ghosh, 2020). With the widespread use of the global system for mobile communication (GSM), mobile phone technology has converged with radio to make it more interactive (Hampson et al., 2017). The convergence of traditional radio with the internet has given unprecedented access to rural areas. An example is the Radio Farm Forum in Zambia, which focuses on the common problems of resource-deficient farmers (Bobbili et al., 2006). Callers would receive market information on what is being sold, extension messages, information about the buyer and information to buy or sell agricultural commodities (Jairath & Yadav, 2012). The convergence of rural radio and the internet in Kenya provided farmers with information that could be used for the improvement of their agricultural activities (Munyua & Hilda, 2007). However, mobile phones face demand-side limitations such as connectivity issues, limited content, illiteracy (in text-based communication) and inadequate poor infrastructure such as electricity to charge phones (Food and Agriculture Organization of the United Nations [FAO], 2019; Goyal & González-Velosa, 2013). The gender gap in mobile ownership has been constant in Sub-Saharan Africa, whereas in South Asia, it has reduced from 26% in 2017 to 19% in 2020. In LMIC, there is a mobile gender gap of 10% with women having lower access to mobile phones than men; however, this gap is expected to close in the next five years (Rowntree, 2020).

Modern agricultural practices are highly knowledge-intensive, innovative and multidimensional (Deichmann et al., 2016). Unlike cell phones, smartphones can bring sophisticated science-based agricultural guidance to smallholder farmers to improve productivity, especially under rapidly changing economic and environmental conditions (B. Ahmad et al., 2024; Aldosari et al., 2019; Steinke et al., 2019). Smartphone allows collecting data on households, farms or even plots of individuals, which can then be used to select and return individually customized advisory content using applications (Fabregas et al., 2019; Panda, 2020; Sinha et al., 2018). For example, in Mexico, AgroTutor mobile application provided timely and agriculture-specific local information on cropping practices, future prices, weather information and forecasts. Farmers can also contribute information on soil, agriculture practices and yield information through their mobile phones (Carlos et al., 2020). With the rise of internet access, the rate of ownership

of smartphones in developing countries has increased substantially (see also Figure 3). Smartphones also offer new opportunities for video messaging. Increasing mobile phone penetration and internet connectivity in rural areas have made it easier and cheaper to distribute video content through different mediums (K. M. Singh et al., 2015). It has provided information access to poor and marginalized farmers across geographically dispersed farmers from different socio-economic backgrounds overcoming space and social barriers (Baumüller, 2013; Bello-Bravo et al., 2019; Fu & Akter, 2012). Videos used to complement agricultural extension strategies during farmer training can help overcome gender and illiteracy barriers related to information access (Bello-Bravo et al., 2015).

In contrast to cell phones, farmers can use smartphones to make videos of agricultural practices or shoot video clips on pests and many other aspects to share with other farmers and extension workers (Mwalukasa et al., 2018). Video-based messaging is an appropriate tool for communicating knowledge-based technical agricultural practices. It has tremendous potential for enhancing dissemination programs or specific research and development projects to enable more resilient, inclusive and democratic systems (Sousa, 2019). Studies show that video messaging on smartphones increases outreach and adoption of agricultural practices six to seven times in comparison to one-to-one exchanges between farmers (Sousa, 2019). It improves farmer-to-farmer exchange and increases the dissemination of agriculture practices. Another study from Bangladesh shows that video-facilitated discussions led to changes in farmers' attitudes, increased knowledge and encouraged them to adopt complex agricultural innovations (Chowdhury et al., 2015).

The use of video-based messaging has broadened in recent years. For example, it can be used as part of social media platforms like WhatsApp and YouTube with massive outreach. Regarding YouTube, farmers (and other actors) can produce, share, watch and comment videos. Using WhatsApp, farmers can also produce, share, watch and comment videos as well as short text, photos and web links (Pattabhi et al., 2023). Users can share information anytime and anywhere without being concerned about background disturbances. These methods are more participatory as farmers can interact and discuss among themselves, which was not possible through mobile advisory services. Even shy and hesitant farmers can use the platform to connect, share and provide feedback to one another, extension agents and researchers (Thakur & Chander, 2018). YouTube and WhatsApp provide farmers with the opportunity to share short video clips on localized issues with each other, enabling the decentralization of information provision beyond traditional extension-service-led video-based messaging. Farmers can receive instant feedback to enhance diagnosis and guidance (Mittal et al., 2010). Arguably, these tools have the potential to democratize information by making it accessible to all the users.[4] In the next section, we discuss the main findings of our review.

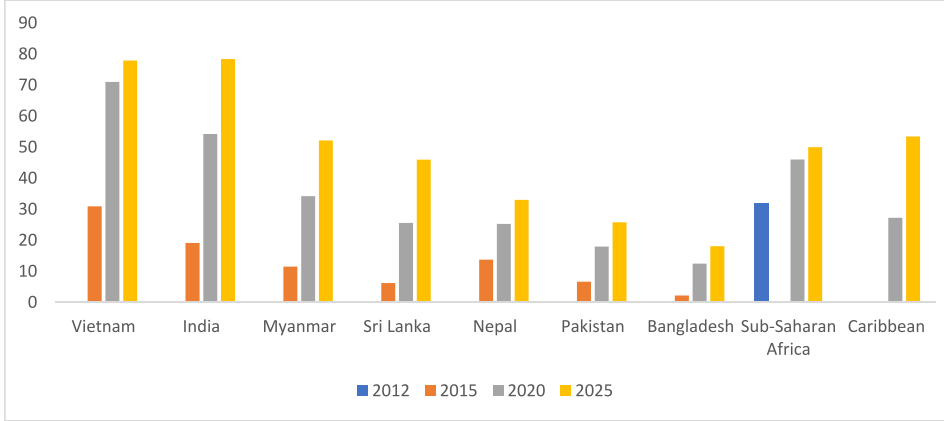


**FIGURE 3** Penetration rate of smartphones in emerging economies. Source: Statista (2024).

## 6 | DISCUSSION

Smartphones have the capability to make videos on farming practices that could be shared with extension workers to receive quick feedback, which was not possible through analogue cell phones. In contrast to traditional ICT like television and video viewing, mobile-based video messages can capture and share localized information on crops and pests with extension departments instantly (Ahmed & Harshavardhan Reddy, 2021; Krell et al., 2021). Video-based messaging using mobile phones has the potential to disseminate technical and complex agricultural practices effectively and swiftly (Jain et al., 2014; Mukherjee & Jha, 2024; Wijeratne & Silva, 2014). As smartphone technology advances, one can expect high-definition videos, 3D visualization and virtual reality to provide farmers with immersive learning experiences. Farmers will have access to more sophisticated mobile applications tailored to specific needs. Furthermore, accessing information on a real-time basis will reduce some uncertainties involved in agricultural production, distribution and marketing. We can anticipate greater collaboration between farmers, agriculture experts, extension workers, researchers and technology developers to create innovative solutions that leverage smartphones for sustainable agriculture.

However, the usage of mobile faces several challenges such as affordability, connectivity, literacy and inadequate infrastructure (Dissanayeke & Wanigasundera, 2014; N. A. Khan et al., 2019). Although there has been an increase in ownership and accessibility, there remains a gender gap. Women are 10% less likely to own a mobile phone in low- and middle-income countries.[5] Also, there is inequality in mobile internet usage between men and women as women are 23% less likely to use mobile internet.[6] However, despite these challenges, there is a steady increase in the ownership of mobile phones in developing countries. As mobile phone penetration continues to increase in developing countries, more and more farmers have started accessing, learning and adopting new agricultural practices (Kansiime et al., 2019). With the availability of cheap phones, better infrastructure and cheap data plans, it is expected that smartphone usage for agriculture extension will rise in future (Mapiye et al., 2021).

With the increase in the use of smartphones in developing countries, the use of social media apps like WhatsApp, YouTube and Facebook has provided opportunities for disseminating agriculture extension messages. Unlike traditional media, these apps allow users to engage directly to generate, shape and share information. Information sharing can take place anytime and anywhere unlike radio and television broadcasts. WhatsApp, unlike traditional media, allows real-time video chatting, allowing farmers to communicate with extension agents or other farmers, even when they are in the field (Sandeep et al., 2022). Information can be stored for later viewing and sharing. YouTube is another social media platform where young farmers and agriculture professionals search for information on new agriculture technologies and agriculture innovation. With the rise of modern ICT, the scope for direct communication between farmers and extension agents or other farmers, either as part of one-to-one or one-to-many interactions, has greatly expanded. In the future, social media platforms will evolve and may integrate with technologies like drones, sensors and Internet of Things (IoT) devices, enabling farmers to collect real-time data from their fields and share that with their networks. This approach could improve decision-making and enhance productivity and resource efficiency. With the use of data analytics and artificial intelligence, social media platforms and other applications may offer personalized extension services to farmers based on factors such as location, crop type, soil conditions, weather patterns and previous interaction history for ensuring relevance and effectiveness of information service (Tzachor et al., 2023).

However, due to a lack of regulation, information shared over social media platforms could be misleading or fake and needs to be checked by users. Users also need to be trained on what could be fake and misleading information. The free nature of information sharing over social media platforms should be regulated by moderation to safeguard the privacy and safety of the users. The use of social media platforms requires some digital literacy and access to the internet. However, low-literacy users can make WhatsApp calls to peers and can also watch videos on YouTube. The majority of the farmers are subsistence farmers and cannot afford to buy data packs or own a device to access agricultural information, which restricts the usage (Mehrabi et al., 2021). Despite these challenges, social media

continues to grow with a rapid increase in the number of users. By leveraging the power of technology and social networks, social media platforms have created a more connected, informed and resilient agricultural community. It could be argued that the democratization of information has begun with the advent of apps and social media platforms (Bhattacharjee & Raj, 2016).

## 7 | CONCLUSION

The review paper used a historical perspective to address three research questions that deal with the changing nature of ICT for agricultural extension, its advantages, and challenges, and to what extent modern ICT like smartphones and mobile internet can reach farmers. The contribution of this review paper is three-fold. First, the review adds to the understanding of the existing literature on the evolution of agricultural extension and farming systems from a historical perspective (1950s to the present). Second, it provides a better understanding of the application of ICT and the challenges encountered in disseminating agricultural information corresponding to historical developments in agricultural extension. Third, the review summarizes the potential and challenges of using smartphones and mobile internet to overcome the challenges of traditional ICT and reach farmers to strengthen their understanding of complex modern agricultural practices.

During the 1950s and 1960s, the newly independent countries adopted a centralized approach to controlling all the sectors including agricultural extension. Agricultural information was available to those who had access to print media or owned radio sets. Traditional media like print and radio were largely used to disseminate agricultural information. Other constraints that hindered access to information were low-literacy, and the unavailability of radio signals in the villages. The extension system expanded to T&V in the 1970s and 1980s, strengthening the connection between researchers and farmers for better outreach. However, in the T&V system of extension, scientists developed extension messages without any involvement of farmers. Information was disseminated through extension agents and bi-weekly visits, and not through popular mass media like radio, television and video screening. More recently, extension evolved to an increased focus on pluralistic, participatory and more engaging approaches. The evolution of ICT followed the pathways of extension systems transitioning from traditional (radio, television) to modern ICT (videos, cellular phones and smart phones). To meet the demands of agricultural extension and changes occurring in the farming system, ICT has continuously evolved to address the information needs of farmers, from communicating simple agricultural information practices through radio and television to conveying complex technical practices through videos and mobile phones. ICT has come a long way in addressing the information demands of farmers.

Modern complex agriculture has witnessed changes in the market and natural environment of farming systems. Farmers need quick and real-time information that can help in make better farming decisions. Traditional media like newspapers, radio and television continue to provide agriculture information but face challenges of outreach, accessibility, cost and literacy. Farmers are not able to connect with researchers and have to wait for broadcast time and visits from extension agencies. It has delayed the decision-making of the farmers, which has affected their output and productivity. Recent studies on the use of smartphones and social media apps like WhatsApp, YouTube and Facebook have shown that it is possible to overcome the difficulties in outreach and dissemination of agriculture information in remote locations. Information could be shared as text, audio, weblink and short videos to farmers, researchers and extension officers. It facilitates a bi-directional exchange of information, which allows farmers to generate and disseminate knowledge. These technologies allow us to provide just-in-time information and can overcome time and mobility constraints, which was not possible with traditional media. WhatsApp, YouTube and Facebook are the most used social media apps that have the potential to democratize agriculture information in the future. The findings of this study have practical implications for government extension agencies and agricultural information providers, who are interested in disseminating complex agriculture practices using smartphones and mobile internet to small-scale farmers in developing countries.

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## DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

## DECLARATION OF INTEREST STATEMENT

The authors declare no conflict of interest.

## ORCID

*Rashid Parvez Khan* https://orcid.org/0000-0002-8623-9914
*Thomas Daum* https://orcid.org/0000-0001-7575-1763

## ENDNOTES

[1] It is argued that the sharing and dissemination of information and institutionalization of modern agricultural research emerged in Britain during the second half of the 19th century (Boon, 2010). In 1850, discussions began at the universities of Oxford and Cambridge as to how the educational needs of a distant and growing population could be served. In the United States and Canada, formal agricultural extension started during the late 1800s; and in France, extension services began in 1879 with itinerant agriculturists (Ponniah et al., 2008).

[2] https://www.thepatriot.co.zw/columns/agricultural-extension-services-in-zimbabwe/

[3] https://www.enablersofchange.com.au/the-modern-evolution-of-extension/

[4] https://www.g-fras.org/en/good-practice-notes/social-media-new-generation-tools-for-agricultural-extension.html

[5] This categorisation is based on the World Bank's country classification and includes countries the World Bank classifies as low-income, lower-middle income and upper-middle income.

[6] https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2019/02/GSMA-The-Mobile-Gender-Gap-Report-2019.pdf

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