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"INTEGRATING ICT IN AGRICULTURAL EXTENSION IN EGYPT: CURRENT STATUS, CHALLENGES, AND INTERNATIONAL INSIGHTS"

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ABSTRACT

Agricultural extension services play a pivotal role in achieving sustainable rural development, especially in developing countries facing constraints in food production and distribution. This study explores the evolution of agricultural extension in Egypt, highlighting the transition toward electronic extension (e-extension) through the integration of information and communication technologies (ICTs). The paper analyzes the structural challenges of the traditional extension system, evaluates Egypt's key ICT-based initiatives (such as VERCON, RADCONE, and NARIMS), and discusses their effectiveness in enhancing communication between researchers, extension agents, and farmers. Drawing from global experiences in countries like the United States, India, Japan, and China, the study outlines best practices and core requirements for successful ICT adoption in agricultural advisory systems. The findings underscore the urgent need to modernize Egypt's extension services through investment in digital infrastructure, capacity building, and the institutionalization of public-private partnerships. This integration is essential to bridge the rural-urban information gap, empower smallholder farmers, and support sustainable agricultural growth.

KEYWORDS: Information and Communication Technologies, Agricultural Extension, Digital Transformation, Rural Development, Electronic Extension Systems.

1. INTRODUCTION

The agricultural sector in Egypt constitutes one of the principal pillars of the national economy. It contributes approximately 14.5 percent of the gross domestic product and employs nearly 21 percent of the country's total labor force (World Bank, 2022). Its strategic importance extends beyond its direct economic contribution. Agriculture represents a vital source of national income through export revenues and its role in improving the balance of payments. In addition, it plays a central role in poverty reduction and job creation, particularly in rural areas, where more than half of the population remains directly or indirectly connected to agricultural, production, marketing, and agro-industrial activities.

Despite this significance, the sector faces substantial structural challenges, most notably the persistent gap between domestic agricultural production and the rapidly growing food demand of the population. Population growth rates have consistently outpaced the growth of agricultural output. The total population increased from approximately 18.97 million in 1947 to more than 103 million in 2022, while per capita agricultural land declined from 0.3 feddan to nearly 0.11 feddan over the same period. Although the state has implemented extensive land reclamation programs, these efforts have often been offset by the loss of comparable areas of arable land as a result of urban expansion (Central Agency for Public Mobilization and Statistics [CAPMAS], 2022).

In light of these challenges, agricultural extension emerges as a strategic instrument for advancing agricultural and rural development. It facilitates the transfer of technology, strengthens human capital, bridges scientific research with field realities, and promotes the adoption of modern production practices. Through these functions, extension services contribute to improving agricultural productivity, increasing farmers' incomes, and enhancing their overall standard of living. The International Food Policy Research Institute emphasizes that agricultural extension, often referred to as agricultural advisory services, plays a central role in raising productivity, promoting food security, improving rural livelihoods, and fostering pro poor economic growth (IFPRI, 2020).

The agricultural extension system in Egypt has undergone several historical phases. Prior to the mid twentieth century, extension activities were largely fragmented and implemented by certain cooperatives and commercial entities. A more institutionalized framework emerged following the Food and Agriculture Organization conference in 1953, which led to the establishment of specialized extension centers. Subsequently, Ministerial Decree No. 744 of 1982 formally linked the agricultural extension apparatus to the Agricultural Research Center and established a dedicated department for applied extension (Central Administration for Agricultural Extension [CAAE], 2012). Despite these organizational developments, the system has faced increasing criticism over the past decades. Key concerns include inadequate professional training of extension personnel, the absence of stable policy frameworks, limited financial and human resources, and a dramatic decline in the number of extension agents from approximately 25,000 in 1990 to fewer than 1,800 in 2021 (Mansour et al., 2022). The system also suffers from weak coordination between research and extension institutions, insufficient locally tailored programs, and deficiencies in evaluation and impact assessment mechanisms.

Amid global transformations, modernizing agricultural extension systems has become imperative. Digital transformation and the integration of information and communication technologies into extension work represent one of the most promising pathways toward this objective. The expanding use of digital tools offers tangible opportunities to enhance efficiency, reduce operational costs, and broaden access to agricultural information and services, particularly in remote rural communities. Qamar (2005) argues that contemporary reform of agricultural extension systems requires the adoption of decentralization, privatization, pluralism, and the effective integration of information and communication technologies.

The concept of electronic agricultural extension, commonly termed e Extension, marks a substantive shift in the philosophy and practice of extension services. It strengthens linkages among research institutions, extension agents, and farmers, while providing timely, real-time information on weather conditions, market prices, input availability, and recommended agricultural practices. This transformation is particularly critical in Egypt, given the aging extension workforce and the significant decline in personnel resulting from the suspension of new appointments since 1984, factors that have constrained the effectiveness of conventional extension approaches (Mansour et al., 2022). International experiences in the United States, India, Japan, and China demonstrate the capacity of information and communication technologies to restructure agricultural extension systems through flexible and integrated models that combine research, learning, and advisory services. For

example, the Cooperative Extension System in the United States and the e Choupal initiative in India illustrate how digital platforms can empower farmers to access markets, improve decision making, and enhance productivity (Hanafy, 2015).

1.1. Research Problem

Despite the remarkable technological advances in the field of information and communication technologies (ICTs), agricultural extension in Egypt continues to rely predominantly on conventional approaches characterized by procedural rigidity and slow knowledge dissemination. This reliance has constrained the effectiveness of transferring agricultural innovations to farmers, particularly in rural areas where access to timely and reliable information remains limited.

The core problem lies in the absence of meaningful integration between agricultural extension institutions and the national digital infrastructure. This gap is compounded by insufficient capacity building for extension personnel and the lack of coherent, forward-looking policies governing the adoption and institutionalization of ICTs within extension practice. Furthermore, the extension system exhibits a persistent knowledge mismatch between farmers' actual needs and the advisory content currently delivered. This discrepancy restricts farmers' ability to enhance productivity and fully benefit from modern agricultural technologies. Accordingly, the present study addresses the structural and operational challenges that impede the effective integration of ICTs into the Egyptian agricultural extension system. It seeks to identify actionable pathways for activating digital transformation within a comprehensive framework that accounts for the economic, social, and technical specificities of the agricultural sector.

1.2. Research Objectives

Building on the preceding discussion, this study aims to analyze the current status of the agricultural extension system in Egypt, with particular emphasis on the extent to which information and communication technologies are integrated within its institutional and operational structures. To achieve this overarching aim, the study pursues the following specific objectives:

1. To examine the existing patterns and levels of ICT utilization within the Egyptian agricultural extension system.
2. To identify and diagnose the principal institutional, technical, and human constraints that hinder the effective integration of ICTs into extension practice.
3. To review and analyze successful international experiences in applying ICTs to agricultural extension and to derive relevant lessons for the Egyptian context.
4. To assess the readiness of both the extension apparatus and farmers in Egypt to adopt electronic extension models.
5. To propose a comprehensive strategic framework for integrating ICTs into the Egyptian agricultural extension system in a manner that enhances its effectiveness, responsiveness, and long-term sustainability.

In light of these objectives, it becomes evident that integrating information and communication technologies into the agricultural extension system in Egypt is no longer a discretionary policy option. Rather, it constitutes a strategic imperative for advancing sustainable agricultural development, strengthening food security, empowering smallholder farmers, and reinforcing the resilience of the rural economy.

1.3. Theoretical Framework and Literature Review

Understanding the nature and significance of agricultural extension, as well as the integration of information and communication technologies (ICTs) within this domain, requires a comprehensive theoretical perspective grounded in the core concepts of agricultural development, digital transformation, and rural learning systems. Agricultural extension functions as a critical linkage mechanism between agricultural research outputs and on farm production practices. It represents a strategic instrument for advancing sustainable development and improving rural livelihoods by fostering knowledge construction, guiding behavioral change, and supporting informed decision making within agricultural environments.

Contemporary scholarship emphasizes that modern agriculture is no longer based solely on traditional production factors such as land, labor, and capital. Rather, it increasingly depends on accurate knowledge, timely information, and digital technologies. International projections indicate that by 2050, global agricultural systems will need to increase production by approximately 60 percent to meet the demands of a population exceeding 9.6 billion people. Within this context, ICTs are expected to play a central role in enhancing agricultural decision making and accelerating knowledge dissemination (World Bank, 2016).

The Food and Agriculture Organization

underscores that digital technologies have become among the most influential tools for rural development, given their capacity to reduce spatial and temporal barriers, expand access to information, and strengthen the performance of agricultural systems (FAO, 2014). The expanding application of ICTs in agriculture is commonly conceptualized under the term electronic agriculture, or e agriculture, which seeks to narrow digital and knowledge gaps between developed and developing countries, as well as between urban and rural areas.

From a conceptual standpoint, ICTs refer to an integrated system encompassing hardware, software, networks, and applications that enable the collection, processing, exchange, and dissemination of data and information in textual, visual, or auditory formats through computers, the internet, smartphones, digital broadcasting platforms, and related technologies (World Bank Group, 2018). As Asif et al. (2017) argue, information constitutes an economic resource comparable in importance to capital and land and serves as a decisive factor in the adoption of agricultural innovations. Empirical evidence further demonstrates that digital agriculture can generate economic opportunities by enhancing productivity, improving resource allocation efficiency, strengthening environmental management, and facilitating market participation. It also contributes to improved rural governance, human capital formation, and expanded access to education and health services (Kaske et al., 2018). Complementing these findings, O'Dea (2020) reports that a 10 % increase in high-speed internet penetration is associated with an estimated 1.3 % rise in economic growth, underscoring the strong linkage between digital transformation and rural economic development.

Saravanan et al. (2015) classify the core applications of information and communication technologies in agricultural extension into a set of interrelated functional domains. These applications extend beyond simple information dissemination and instead reshape the operational logic of extension systems. The principal functions include the following:

- Facilitating the exchange of knowledge and practical expertise among key stakeholders in the agricultural sector, including researchers, extension agents, agribusiness actors, and farmers.
- Improving timely access to specialized agricultural information, thereby reducing informational asymmetries and enhancing the relevance of advisory services.
- Enabling interactive engagement between farmers and extension personnel through intelligent diagnostic applications, such as Plantix, which support real time identification of crop diseases and pest infestations.
- Supporting agricultural decision making through the use of big data analytics and geographic information systems, which allow for spatial analysis, risk assessment, and precision management.
- Strengthening linkages between farmers and markets, while enhancing the bargaining power of smallholder producers through improved access to price information and supply chain networks.
- Enhancing the monitoring and evaluation of extension activities through digital tracking systems that generate reliable performance indicators.
- Supporting capacity building among extension agents and field staff, particularly in remote areas, through distance learning platforms and digital training tools (Swanson & Rajalahti, 2010).

Collectively, these functions illustrate that ICT integration in agricultural extension represents a systemic transformation rather than a purely technical upgrade.

Within the Egyptian context, national studies reveal a substantial gap between the technological potential available and the actual application of digital tools in extension practice. The number of extension agents has declined sharply, while the extension budget decreased from approximately 40 million Egyptian pounds in 1995 to nearly 150,000 pounds in 2017. Moreover, new recruitment has been suspended since 1984 (Mansour et al., 2022). This institutional contraction has compelled the state to rely increasingly on technological alternatives to compensate for the shortage of human resources and to improve the efficiency of information delivery to farmers.

The literature further highlights the importance of international experiences in informing national policy reform. The United States, India, and China are frequently cited as leading examples of successful ICT integration within agricultural extension systems. In the United States, an electronic Cooperative Extension framework was established in 1998, and expert agricultural systems were deployed to provide highly specialized digital advisory services (Hanafy, 2015). In India, the government promoted the establishment of village level agricultural information centers and supported the

digitization of agricultural data, thereby enabling more than 110 million farmers to access electronic extension services. In China, a nationwide network of agricultural websites was developed to deliver technical and market oriented recommendations, supported by digital databases, interactive online services, and multimedia resources tailored to agricultural producers. Collectively, these models have contributed to reducing operational costs, improving service efficiency, and expanding the geographic reach of extension delivery.

A review of the Egyptian extension landscape indicates promising opportunities for modernization through the adoption of an integrated electronic extension model grounded in robust digital infrastructure, informed by international best practices, and reinforced by public private partnerships. Nevertheless, successful implementation requires overcoming several structural constraints, including limited digital literacy in rural communities, inadequate technological competencies among extension personnel, and the absence of coherent and supportive policy frameworks. Accordingly, the digital transformation of agricultural extension should be conceptualized as a comprehensive reform process rather than a purely technical intervention. It necessitates the development of reliable infrastructure, sustained human capacity building, and a flexible regulatory and institutional framework capable of ensuring both the effectiveness and long-term sustainability of the transformation.

2. LITERATURE REVIEW

Information and communication technologies have assumed a pivotal role in advancing sustainable agricultural development, enhancing the efficiency of extension systems, and improving farmers' livelihoods, particularly in developing countries. Halewood and Surya (2012) reported that enabling farmers to access market information through ICT applications resulted in income increases of up to 36 % in several African countries, including Kenya, Ghana, Uganda, and Morocco.

Recent empirical studies further demonstrate the growing integration of technological tools in extension service delivery. In Bangladesh, Islam et al. (2017) found that agricultural extension agents relied extensively on mobile phones to perform their duties, with 97.27 % of respondents using them for information gathering, while the use of other digital tools remained comparatively limited. The study also identified a positive association between ICT utilization and factors such as training exposure and job satisfaction. In Kenya, Gwademba et al. (2019) observed that ICT adoption in Tana River County remained modest despite its documented contribution to productivity gains in certain areas. Major constraints included illiteracy, inadequate infrastructure, and an unfavorable political environment. Similarly, in Nigeria, Agwu et al. (2019) reported high levels of ICT usage among researchers and extension personnel, including computers (95.1 percent), internet services (90.2 %), and mobile phones (86.3 %) to meet professional information needs. The authors recommended institutional subscriptions to reduce the costs associated with accessing electronic resources. Attah et al. (2020) found that in Benue State, mobile phones, radio, and television were the most frequently used ICT tools, although inadequate funding and limited training remained persistent barriers. Viola et al. (2021) showed that more than 70 % of Kenyan farmers owned mobile phones and used them to access electronic advisory services, particularly through WhatsApp and Facebook. However, weak infrastructure and limited awareness of modern agricultural information platforms constrained broader utilization.

Within the Egyptian context, local studies have examined structural and behavioral constraints affecting ICT adoption in agricultural extension. Harhash (2019) found that attitudes toward modern communication tools among farmer leaders were negatively associated with age and positively correlated with education level and smartphone ownership. Identified barriers included weak infrastructure, widespread illiteracy, and unstable mobile networks. Elhamoly et al. (2019) reported limited use of agricultural websites among extension agents in Kafr El Sheikh, with 60 percent demonstrating low levels of engagement due to limited awareness, weak content quality, and professional workload pressures. Draz (2020) indicated that WhatsApp, Messenger, and Facebook were the most accepted social media platforms among extension specialists, with most respondents emphasizing the importance of free or low cost access. In Beheira Governorate, Abdel Malik (2021) found that 71.6 % of farmers reported high levels of benefit from social media in receiving extension recommendations, with positive correlations between benefit levels and frequency of use, farm size, and social participation.

From a health and crisis management perspective, Melouk and Saker (2021) assessed farmers' perceptions of ICT applications during the COVID 19 pandemic and found that 82.3 % demonstrated

moderate to high levels of awareness. Education, income, and exposure to agricultural information were significant positive determinants of this awareness. Saker (2021) further observed that 67.86 % of extension agents reported moderate to high levels of mobile phone use in extension work, despite challenges related to internet costs and limited technical infrastructure. El Kadi and Fayiez (2022) reported that 88.5 % of researchers benefited from agricultural websites at moderate to high levels during the pandemic, with significant associations linked to years of experience and hours of internet use. Finally, Abd Elfatah and Elkholy (2022) documented the limited implementation of the Smart Farmer Card system in selected villages of Gharbia Governorate, citing constraints such as shortages of extension personnel, limited capacities of agricultural cooperatives, and operational malfunctions in distribution systems.

Collectively, previous studies underscore the diversity of ICT applications within agricultural extension systems while simultaneously highlighting the persistent structural limitations that constrain effective implementation. These challenges include inadequate infrastructure, insufficient training, and weak institutional linkages between extension services and research institutions. The literature consistently emphasizes the necessity of leveraging contemporary technological advancements to compensate for the decline in extension personnel, improve service efficiency, and promote equitable access to agricultural knowledge across rural communities.

3. PRACTICAL APPLICATIONS OF INFORMATION AND COMMUNICATION TECHNOLOGIES IN EGYPTIAN AGRICULTURAL EXTENSION

Over the past decades, Egypt has launched a series of initiatives and projects aimed at integrating information and communication technologies into the agricultural extension system. These efforts have sought to address the structural limitations of conventional extension approaches and to capitalize on digital advancements in delivering agricultural knowledge to farmers. The practical applications of ICTs in Egyptian extension can be broadly categorized into three principal tracks: the development of digital infrastructure, the deployment of diverse technological tools and platforms, and the implementation of national projects in partnership with international organizations.

3.1. ICT Tools Utilized in Egyptian Agricultural Extension

Recent years have witnessed a gradual expansion in the use of various ICT tools within Egyptian agricultural extension. The most prominent tools include the following:

Personal Computers: Although the cost of acquiring computers has declined over time, their use in rural Egypt remains relatively limited. Approximately 41.8 % of rural residents reported computer usage, with noticeable variation across governorates (Ministry of Communications and Information Technology [MCIT], 2021). Nevertheless, computers have contributed significantly to extension operations, particularly in data preparation and analysis, the development of training materials, digital mapping, and the establishment of geographic databases using geographic information systems.

Agricultural Expert Systems: Expert systems represent intelligent digital platforms designed to simulate human expertise in generating agricultural recommendations. Egypt began utilizing such systems in 1998 through the Central Laboratory for Agricultural Expert Systems in collaboration with the Food and Agriculture Organization. These systems provide crop specific recommendations for major commodities such as wheat, tomato, strawberry, and grape. Access has been made available to farmers through digital media and specialized online portals, including the VERCON platform. www.vercon.sci.eg

Internet Services: With the number of internet users in Egypt exceeding 49.5 million in 2019 (MCIT, 2021), the internet has become a core instrument in extension practice. It facilitates the dissemination of advisory content, the delivery of distance training programs, and the strengthening of linkages between research institutions and farming communities. The expanding reach of internet services has reduced geographic constraints and accelerated the transmission of agricultural information.

Mobile Phones: Mobile technology has emerged as one of the most effective tools for reaching farmers, particularly given that mobile subscriptions surpassed 103 million in 2021 (MCIT, 2021). Smartphones enable immediate access to advisory applications, crop monitoring services, real time price information, and direct communication with extension agents. Such capabilities enhance timely and informed decision making at the farm level (David & Cofini, 2017).

Radio and Television: Traditional broadcast media continue to play an important role, especially

in areas with high illiteracy rates. Agricultural television programming remains a significant channel for disseminating extension messages. Notably, the launch of Egypt Agricultural Television in 2011 marked a dedicated effort to provide specialized advisory content to more than 20 million individuals engaged in the agricultural sector (National Media Authority, 2022).

3.2. National Initiatives and Flagship Projects

The Egyptian Ministry of Agriculture, in collaboration with international organizations such as the Food and Agriculture Organization, has implemented several major initiatives aimed at institutionalizing the use of information and communication technologies within agricultural extension services. These projects were designed to strengthen research extension linkages, improve information management, and expand access to advisory services at the grassroots level.

VERCON Network Project: Launched in 2000, the Virtual Extension and Research Communication Network was introduced as a pioneering model for leveraging internet technologies to connect agricultural research centers with farmers. The project sought to establish a two-way communication platform, disseminate reliable agricultural information, and enhance the quality of services provided to smallholder farmers. It involved 96 extension centers across 18 governorates and was supported by the Food and Agriculture Organization in partnership with national institutions, including the Central Laboratory for Agricultural Expert Systems and the Agricultural Research Center (Kora & Kassem, 2010).

NARIMS Project: The National Agricultural Research Information Management System was developed between 2004 and 2006 as a bilingual digital platform for managing agricultural research information. Its primary objective was to compile and organize data related to researchers, research projects, and scientific publications, while linking research institutes to a centralized electronic database. By improving access to structured research information, the system contributed to more effective strategic planning and coordination within the agricultural research sector.

RADCONE Network: The Rural and Agricultural Development Communication Network was specifically oriented toward rural community development. It utilized ICT tools to support agricultural and social services at the village level, with a particular emphasis on enhancing the participation of women and youth in productive activities. Through digital portals and interactive services, the network aimed to foster inclusive rural development and strengthen local capacity building.

3.3. Assessment of the Current Level of ICT Utilization in Egypt

Despite the substantial efforts undertaken to modernize agricultural extension through digital tools, a noticeable gap persists between strategic aspirations and actual implementation. Performance indicators point to several structural and operational limitations.

First, the effective use of ICT tools remains limited in many rural areas due to inadequate digital infrastructure, high operational costs, and insufficient digital competencies among both extension agents and farmers. These constraints restrict the capacity of extension systems to deliver timely and technology driven advisory services.

Second, a pronounced digital divide exists between rural and urban governorates, as well as among different categories of farmers, particularly in relation to gender, age, and educational attainment. This disparity affects equitable access to digital extension services and may reinforce existing socioeconomic inequalities within rural communities.

Third, the financial sustainability of existing digital initiatives remains fragile. Many projects have relied heavily on temporary external funding, which has limited their continuity and long-term institutionalization within the national extension framework.

Fourth, there is a lack of integrated information systems capable of ensuring systematic data exchange among research institutions, extension agencies, and other stakeholders. The absence of a unified national platform that effectively links research outputs with extension delivery mechanisms continues to constrain knowledge transfer efficiency.

3.4. Opportunities for Improvement and Strategic Advancement

Previous experiences indicate that successful integration of ICTs into Egyptian agricultural extension requires a comprehensive and sustained reform agenda. Key priorities include the following:

1. Sustained investment in digital infrastructure, particularly in underserved rural areas, to ensure reliable connectivity and equitable access.
2. Systematic capacity building programs aimed at enhancing the digital literacy and

technological competencies of both extension personnel and farmers.
3. Development of locally relevant, accurate, and user-friendly knowledge content tailored to the specific needs and conditions of target farming communities.
4. Strengthening partnerships with the private sector, civil society organizations, and international agencies to promote innovative and flexible technological solutions.
5. Establishment of a digital monitoring and evaluation system capable of measuring the impact of ICT applications on agricultural performance and rural development outcomes.

Taken together, these measures underscore that the effective digital transformation of agricultural extension in Egypt depends on coordinated institutional reform, sustainable financing mechanisms, and continuous human capacity development.

4. INTERNATIONAL EXPERIENCES IN ELECTRONIC AGRICULTURAL EXTENSION

International experiences in integrating information and communication technologies into agricultural extension systems provide valuable lessons and transferable models. Both developed and developing countries have increasingly incorporated advanced digital tools into their extension frameworks to enhance communication efficiency, broaden access to knowledge, and improve agricultural productivity. The following overview summarizes key experiences as documented by Hanafy (2015).

4.1. The United States

The United States was among the earliest adopters of electronic agricultural extension, beginning in the early 1980s. In 1998, the E Extension initiative was launched, relying on internet-based platforms to deliver advisory services. A nationwide network was developed, linking universities, research centers, and extension agents to provide automated and direct access to scientific information and technical expertise for farmers. A distinctive feature of the American model has been its reliance on expert systems, computer programs designed to simulate the reasoning processes of agricultural specialists and deliver customized technical recommendations for specific production scenarios.

4.2. India

India initiated the development of electronic extension to address the challenges posed by its vast agricultural population, exceeding 110 million farmers, and their wide geographic distribution. Village information centers equipped with computers and internet connectivity were established, and rural youth and women received targeted training to use these digital tools. In addition, electronic kiosks were introduced to provide free access to information on market prices, land records, and agricultural production. The government encouraged the partial privatization of extension services, engaging nongovernmental organizations and local enterprises in service delivery.

4.3. Canada

In Canada, information technology was integrated into agricultural extension beginning in the 1990s. A national online agricultural information network was developed, offering comprehensive data on crops, machinery, market prices, and human resources. Distance learning programs were expanded, and research institutions, together with nongovernmental organizations, were encouraged to provide integrated digital advisory services through online platforms.

4.4. Japan

Japan invested substantially in strengthening digital infrastructure within rural communities. Extension centers were equipped with internet connected computers, and extension personnel received specialized training in database management and electronic communication. Strong collaboration was established among governmental agencies, private sector actors, agricultural schools, and rural financial institutions to deliver coordinated digital services. These centers provide farmers with information on research findings, market prices, planting seasons, suppliers, and agricultural enterprises.

4.5. China

China developed multiple electronic platforms to support agricultural production and marketing, including national agricultural portals and specialized online networks. Digital expert systems, soil analysis software, pest management programs, and geographic information system-based databases were distributed through both online services and digital media. The government prioritized ensuring free or low-cost access to these resources through extension centers and internet platforms.

4.6. South Korea

South Korea established more than 150 agricultural extension centers equipped with internet services, enabling over 5,000 farmers to communicate directly with experts via electronic mail and interactive forums. A dedicated agricultural market portal was launched to provide detailed information on products, prices, and agribusiness companies, while also facilitating online negotiation and purchasing processes. www.agrotrade.net

4.7. Additional Experiences

In Sri Lanka, a network of 550 extension offices managed by trained agricultural educators delivers distance education services using digital tools to support farmers. In Chile, the FARM Net network, funded by the Food and Agriculture Organization, was introduced to disseminate agricultural, health, and educational information through internet and radio channels. The initiative achieved a reported 40 percent reduction in information delivery costs. In Somalia, given the country's vast territory and limited infrastructure, interactive radio has been employed as a practical means of delivering agricultural lessons and advisory content to mobile and dispersed rural communities. Collectively, these international models demonstrate that the success of electronic agricultural extension depends on sustained infrastructure investment, institutional coordination, human capacity development, and policy support tailored to national contexts.

4.8. Lessons Learned from International Experiences

A comparative review of successful international models reveals three core elements that consistently underpin effective digital transformation in agricultural extension systems.

First, sustained investment in digital infrastructure is essential. This includes expanding reliable internet connectivity, establishing well equipped extension and information centers, and ensuring access to appropriate hardware and technological resources. Without a stable infrastructural foundation, digital extension initiatives remain fragmented and limited in reach.

Second, human capacity development constitutes a decisive factor. Successful experiences demonstrate that training extension agents and farmers in the effective use of digital tools is as important as the technologies themselves. Building digital literacy and technical competencies enhances adoption rates, improves service quality, and strengthens the overall impact of electronic advisory systems.

Third, the localization of content and technological solutions is critical. Adapting digital resources to the cultural, linguistic, and socioeconomic contexts of farmers ensures relevance, accessibility, and practical applicability. Generic or externally designed systems tend to underperform unless tailored to local production systems and information needs.

These experiences further highlight the value of participatory governance models that integrate the roles of government institutions, private sector actors, research organizations, and community-based entities. Such collaborative frameworks contribute to financial sustainability, operational flexibility, and broader impact. Moreover, international evidence underscores the importance of adopting a comprehensive national strategy for digital agricultural extension. An effective strategy should integrate credible knowledge content, context appropriate technologies, and robust monitoring and evaluation mechanisms capable of measuring performance outcomes and responding dynamically to market fluctuations and climatic variability.

5. ANALYSIS OF EGYPTIAN EFFORTS TO INTEGRATE INFORMATION AND COMMUNICATION TECHNOLOGIES INTO AGRICULTURAL EXTENSION

Egypt has undertaken multiple initiatives to modernize its agricultural extension system through the integration of information and communication technologies, in response to increasing pressures on the agricultural sector and accelerating global digital transformation. These efforts have concentrated on three principal dimensions: upgrading telecommunications infrastructure, activating digital tools and platforms, and implementing national projects in collaboration with international institutions, most notably the Food and Agriculture Organization.

5.1. Current Status of Information and Communication Technologies in Egypt

Although telecommunications infrastructure in Egypt dates back to the mid nineteenth century, substantive digital transformation has accelerated markedly over the past two decades. According to reports issued by the Ministry of Communications and Information Technology, the gross domestic product of the communications and information technology sector increased from 107.8 billion Egyptian pounds in 2020 to 125 billion pounds in 2021, reflecting an annual growth rate of 16.1 percent (MCIT, 2021). The sector's contribution to national

gross domestic product rose from 2.8 percent in 2011 to 4.7 percent in 2021 (CAPMAS, 2022), underscoring its expanding role in supporting multiple development sectors, including agriculture.

Available data further indicate substantial growth in internet and mobile phone usage. Internet users exceeded 49.5 million individuals in 2019, representing 50.2 percent of the population, while mobile subscriptions surpassed 103.5 million in 2021 (MCIT, 2021). These indicators point to a promising technological foundation that can be leveraged to enhance agricultural extension services and broaden digital outreach in rural areas.

5.2. ICT Tools and Applications in Egyptian Agricultural Extension

In addition to the tools previously discussed, the Egyptian extension system has incorporated several specific digital applications.

1. Agricultural expert systems have been developed since 1991 through the Central Laboratory for Agricultural Expert Systems. These systems provide specialized knowledge packages for major crops such as wheat, tomato, and grape, enabling farmers to obtain precise technical recommendations via computer-based applications and internet platforms.
2. Internet based extension networks, notably the Virtual Extension and Research Communication Network established in 2000, have linked extension centers, research institutions, and farmers through internet enabled communication infrastructure. Arabic language interfaces were introduced to facilitate usability and enhance accessibility for local users (Kora & Kassem, 2010).
3. Mobile phones and short message services currently represent the most widely utilized tools, particularly in areas with limited internet connectivity. These services are used to disseminate updates on weather conditions, market prices, and recommended agricultural practices, thereby supporting timely decision making among farmers.
4. Broadcast media continue to complement digital platforms. The Egypt Agricultural Channel, established in 2011 under Law No. 1493, delivers specialized advisory programming targeted at farmers and fishers. It provides updates on agricultural and environmental developments, highlights successful rural initiatives, and promotes practical field-based experiences (National Media Authority, 2022). Collectively, these efforts demonstrate a gradual yet incomplete transition toward digitally enabled agricultural extension, characterized by expanding technological adoption alongside persistent structural constraints.

5.3. National Projects for the Application of ICT in Agricultural Extension

First, the VERCON Project, implemented between 2000 and 2002, was launched in collaboration with the Food and Agriculture Organization as a pioneering initiative to utilize internet-based communication in linking researchers, extension agents, and farmers. The project aimed to enhance the quality of extension services and to narrow the gap between scientific knowledge and field level agricultural practice. A total of 96 extension centers across 18 governorates were connected through a dedicated communication network. The platform provided interactive multimedia content presented in clear and accessible language to facilitate effective user engagement (Kora & Kassem, 2010).

Second, the National Agricultural Research Information Management System, developed between 2004 and 2006, represents an integrated platform for collecting and exchanging information on researchers, research projects, scientific publications, and five-year research plans. The system was designed to strengthen research planning and strategic coordination within the Agricultural Research Center. It features a bilingual interface to enhance accessibility and promote broader institutional use.

Third, the RADCONE Network, implemented between 2004 and 2008, was established to support agricultural and rural development through the provision of tailored knowledge content and the promotion of community participation in designing and implementing agricultural activities. The initiative placed particular emphasis on empowering rural women and youth by facilitating their access to financial and technical resources and by strengthening local engagement in development processes.

6. CHALLENGES AND CONSTRAINTS FACING ELECTRONIC AGRICULTURAL EXTENSION IN EGYPT

Despite the significant potential offered by information and communication technologies for developing the agricultural extension system, the implementation of electronic agricultural extension in the Egyptian context continues to face several challenges that limit its effectiveness and dissemination, particularly in rural areas. These challenges encompass technical, human, institutional, and cultural dimensions, necessitating comprehensive analysis to understand the current

situation and formulate policies to address them.

6.1. Technical and Infrastructure Challenges

One of the primary obstacles to implementing electronic agricultural extension is the need for robust infrastructure, including stable communication networks, availability of computers, internet access, and reliable electricity supply, which are lacking in many villages and remote agricultural areas. Digital extension requires an integrated infrastructure that includes communication lines, satellite systems, and computer laboratories, all of which demand substantial investment, particularly during the initial establishment phase (Hanafy, 2015). In addition, many agricultural extension centers still lack modern computer equipment or specialized software and face difficulties in maintenance and periodic updates. Technologies such as high-speed internet, digital imaging tools, and intelligent systems remain inaccessible in certain rural environments.

6.2. Human and Knowledge Challenges

The human factor represents one of the most critical determinants of the success of electronic agricultural extension. A considerable number of extension agents lack adequate technological skills and are unfamiliar with the effective use of computers, internet services, and mobile applications for delivering knowledge to farmers. This situation is largely attributable to the absence of effective and sustainable training programs aligned with digital transformation, as well as the lack of professional incentives that encourage self-learning and continuous development (Swanson & Rajalahti, 2010). On the other hand, many farmers, particularly older or illiterate individuals, encounter difficulties in interacting with digital tools. This limitation reduces the effectiveness of electronic extension and underscores the need to simplify content, provide user friendly visual and audio materials, and offer direct technical support in the field.

6.3 Institutional and Organizational Challenges

The absence of a clear regulatory framework for electronic agricultural extension constitutes a major barrier to development. Efforts remain fragmented among ministries, research institutes, and executive agencies, without a unified body responsible for planning, coordinating, and evaluating digital extension programs. Moreover, many projects launched in this field have relied on temporary support from international organizations and have not been incorporated into the state budget or long-term strategic programs. As a result, sustainability has been weak, and several initiatives have ceased upon the conclusion of external funding. Experiences such as VERCON, RADCONE, and NARIMS demonstrate that project continuity depends on the existence of a national plan for financing, operation, maintenance, and training (Kora & Kassem, 2010).

6.4. Cultural and Behavioral Challenges

Organizational culture and traditional mindsets present additional barriers to the adoption of electronic agricultural extension. Some stakeholders continue to perceive technology as a substitute for extension agents, raising concerns about job reduction or loss of control over advisory content. However, a more accurate understanding emphasizes that electronic extension complements field work rather than replacing it (Hanafy, 2015). Similarly, certain farmers may hesitate to trust digital sources or recommendations generated by automated systems, preferring direct personal interaction with extension agents. This highlights the importance of raising awareness and educating farmers about the role of technology in enhancing productivity, particularly among younger generations of agricultural producers.

6.5 Financial Challenges

Electronic agricultural extension programs in Egypt face significant financial constraints. The extension budget declined from 40 million Egyptian pounds in 1995 to only 150,000 pounds in 2017 (Mansour et al., 2022). Furthermore, most previous projects were not permanently incorporated into the Ministry of Agriculture's financial framework, rendering them vulnerable to discontinuation once external funding ended. Given the high costs associated with establishing digital centers, providing equipment, and training personnel, project sustainability requires innovative financing mechanisms, including partnerships with the private sector and civil society, as well as the introduction of modest service fees during expansion phases.

6.6 Absence of a Unified National Strategy

Egypt still lacks a unified national strategy for electronic agricultural extension that defines clear objectives, performance indicators, and precise distribution of roles among relevant institutions. There is also no central platform to consolidate and coordinate digital content and efforts or to ensure systematic interaction among researchers, extension agents, and farmers. Without such a strategy, it

becomes difficult to ensure integration between agricultural research programs and digital extension services, to verify the quality of delivered content, or to guarantee its alignment with the evolving realities and needs of the agricultural sector.

Proposed Framework for Utilizing Information and Communication Technologies to Support Agricultural Extension in the Arab Republic of Egypt

In light of accelerating global digital transformation and the adverse impact of the COVID 19 pandemic on agricultural extension systems, the adoption of innovative solutions has become essential to ensure the continuity, efficiency, and broader reach of agricultural services, particularly among vulnerable rural populations. This proposal responds to the urgent need for a modern electronic extension model aligned with the state's digital transformation agenda while reflecting the specific structural and socioeconomic characteristics of the Egyptian agricultural sector.

6.7. Conceptual Framework of the Proposal

The proposal centers on the design and development of an integrated digital agricultural extension application compatible with smartphones, tablets, and desktop computers. The platform would provide a comprehensive suite of electronic advisory services targeting farmers, extension agents, and researchers. It would operate through an up-to-date knowledge database and enable direct communication between users and subject matter experts, allowing farmers to present field problems and receive evidence based technical solutions.

The application would operate under the supervision of the Ministry of Agriculture and Land Reclamation in collaboration with faculties of agriculture and national research centers. Implementation would follow a phased approach, beginning with newly reclaimed land projects, including the One and a Half Million Feddan initiative, before expanding to broader agricultural regions.

6.8. Primary Objectives

1. To facilitate farmers' access to reliable and scientifically validated agricultural knowledge.
2. To mitigate the impact of declining numbers of agricultural extension agents by providing scalable digital advisory services.
3. To foster interactive linkages between scientific research institutions and field level agricultural practice.
4. To support agricultural production decisions through real time data and evidence-based recommendations.
5. To promote a culture of digital agricultural extension within rural communities and encourage the adoption of technology driven advisory models.

Proposed Implementing Entities

- •Ministry of Agriculture and Land Reclamation.
- •Faculties of Agriculture at Egyptian universities.
- Agricultural Research Center and specialized research institutes.
- •Ministry of Communications and Information Technology.
- International organizations such as FAO, IFAD, and GIZ.
- Application Components
- Dedicated sections for crop production, livestock production, and fisheries.
- A simplified Arabic interface supported by images and instructional videos.
- Instant advisory services through text, audio, and video communication.
- Updated weather bulletins and seasonal recommendations.
- Databases of common agricultural problems and corresponding technical solutions.
- Interactive forums enabling farmers to exchange experiences and practical knowledge.
- Innovation Features
- Integration of scientific research outputs and applied field expertise within a unified platform.
- Overcoming geographic and temporal constraints traditionally associated with extension services.
- Future integration of artificial intelligence tools for agricultural data analysis and decision support.
- Potential Challenges
- Weak digital infrastructure in certain rural villages.
- Limited technological literacy among some target groups.
- Insufficient and unstable financial and technical support.
- Mitigation Mechanisms
- Organizing structured training and awareness programs for farmers.
- Securing technical support through partnerships with civil society and the private sector.

- Establishing mobile technical support units to address operational and maintenance issues.
- Providing the application free of charge or at a nominal cost.
- Impact Assessment Indicators
- Number of active monthly users.
- Level of user engagement with advisory services.
- Rate of improvement in crop productivity among beneficiaries.
- Overall satisfaction rate based on annual evaluation surveys.

7. CONCLUSION

Experiences from both developed and developing countries have demonstrated that electronic agricultural extension constitutes a fundamental pillar for modernizing the agricultural sector and achieving comprehensive and sustainable rural development. In the Egyptian context, despite serious initiatives launched since the beginning of the twenty first century, digital transformation in agricultural extension continues to face structural challenges related to infrastructure, human resources, organizational culture, financing, and weak institutional coordination.

The study has shown that the success of electronic agricultural extension in Egypt depends on adopting an integrated national vision that places technology at the core of the extension process. This requires prioritizing the development of high-quality digital content, strengthening the capacities of extension agents, and expanding equitable access to digital services for all categories of farmers. The study also underscores the importance of reinforcing partnerships among government institutions, the private sector, and civil society to ensure sustainable financing and the delivery of high-quality digital services.

In light of climate change, market volatility, and rising food demand, the transition to electronic agricultural extension is no longer optional. Rather, it represents a strategic necessity to safeguard food security, promote social equity, and advance rural development in Egypt.

8. RECOMMENDATIONS

1. Formulate a comprehensive national strategy for electronic agricultural extension that clearly defines objectives, responsible institutions, and implementation mechanisms.
2. Improve digital infrastructure in rural areas, particularly internet connectivity, access to devices, and sustainable energy supply.
3. Train and qualify agricultural extension agents in digital tools and techniques, linking performance to professional incentives.
4. Develop simplified and effective Arabic digital agricultural content using multimedia formats appropriate to users' educational levels.
5. Strengthen partnerships among governmental bodies, the private sector, and civil society to ensure sustainable financing and implementation.
6. Establish a unified national electronic platform for agricultural extension providing advisory, training, and interactive services.
7. Design a digital performance and impact evaluation system to ensure continuous improvement and program efficiency.
8. Support vulnerable groups, including rural women and older farmers, through targeted training and field based technical assistance.

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