Review

Digital horizons in agricultural education – leveraging ICTs for a resilient and inclusive system

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ABSTRACT

The escalating global population necessitates a significant increase in food production, placing immense pressure on agriculture and requiring more effective agricultural extension services to meet farmers' information demands in developing nations like India. This paper reviews the role, integration, benefits and challenges of information and communication technologies in modernizing agricultural education and extension. ICT encompasses a wide range of tools, from older media (radio, television) to modern digital technologies (E-learning, social media, CAI, Internet), all vital for fostering skills and disseminating agricultural innovations. Global experience highlights that while ICT offers profound benefits such as increased access, improved quality, reduced costs and enhanced student learning outcomes, its successful integration is not automatic. Key constraints include environmental barriers (poor infrastructure, power outages), cultural barriers (language, English-centric content) and educational barriers (high financial cost, lack of teacher training and institutional resistance to change). Strategic measures necessary for strengthening ICT integration include formulating a comprehensive ICT policy, developing high technological proficiency among all stakeholders, fostering collaboration with community and corporate sectors and implementing continuous training programmes for teachers. Ultimately, while ICT is a powerful instrument for educational and economic growth, its potential in agricultural education can only be fully realized through coordinated strategic action addressing these multifaceted institutional, financial and cultural barriers.

Keywords*:* Agricultural extension, ICT; E-learning; social media; developing nations

INTRODUCTION

As the world's current population will rise from 7.4 to 9.1 billion by 2050, food production will need to increase over this similar time (https://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf). Therefore, to solve agricultural challenges, more effective extension services are necessary for addressing the information demands of farmers in developing nations.

Agricultural extension, also known as agricultural advisory services, plays a critical role in promoting agricultural productivity, increasing food security, improving rural livelihoods and promoting agriculture as a pro-poor economic growth engine. Agricultural extension professionals and institutions all around the world are encouraging agricultural extension and education agents to use information and communication technologies (ICTs) and it can help to speed up the dissemination of agricultural technologies and innovation from research and development organizations to farmers. It helps in farmers' learning, problem-solving and access to viable markets for their crops also (Anon 2011).

Although developing countries, such as India, were able to achieve food self-sufficiency through the green revolution, they are now at risk of losing this self-sufficiency due to the deterioration and decline of natural resources such as soil and water. This will result in stagnation in production and food shortages in the near future as a result of the continuing population growth. Therefore, in these circumstances, ICTs may

be employed as a means of reorganizing agricultural education, research and extension networks across the nation, thereby, fostering the adoption of new agricultural technologies and innovations (Nain et al 2015).

ICT refers to technologies that provide access to information through telecommunications. It is similar to information technology (IT) but primarily focused on communication technologies. This includes the Internet, wireless networks, cell phones and other communication media (Shokeen et al 2022).

In the past few decades, ICTs have been provided to society with extensive array of new communication capabilities. For example, people can communicate in real-time with others in different countries using technologies such as instant messaging, voice over IP (VoIP), and video-conferencing. Social networking websites like Facebook allow users from all over the world to remain in contact and communicate on a regular basis.

People communicate with others across the globe as if they were residing next door as a result of the global village that modern ICTs have established. As a result, ICT is frequently examined in relation to its impact on society through the use of modern communication tools (Tamilselvan and Sivakumar 2019).

ICT encompasses both the Internet-enabled sphere as well as the mobile one powered by wireless networks. It also includes antiquated technologies, such as landline telephones, radio and television broadcast, all of which are still widely used today alongside cutting-edge ICT pieces such as artificial intelligence and robotics (Sumathi et al 2020). It also encompasses the services and applications linked to these technologies, including videoconferencing and remote learning (Khan et al 2015). ICTs are often spoken of in a specific context, such as ICTs in agriculture, healthcare, education or libraries (Abe and Adu 2007).

Education is the single most powerful tool for individual and societal growth. In today's world of rapid technology, global connections and complex challenges, education is the essential foundation. It equips us with the knowledge, skills and critical thinking we need to understand, navigate and actively contribute to our ever-evolving world (Niazi 2025). In technical sense, education is the process by which society through schools, colleges, universities and other institutions deliberately transmit its culture heritage, accumulated knowledge, values and skills from one generation to another. Education is an instrument of cultural change as well social change (Pramanik and Chaudhary 2016).

Education in broad terms means, the life-long process of acquiring new knowledge and skills through both formal and informal exposure to information, ideas and experiences. It is one of the most powerful instruments for reducing poverty, inequality and enhances the competitiveness in the global economy (Dar and Siddique 2020).

It is vital in encouraging self-development because it imparts the knowledge, skills and critical thinking necessary to open up individual opportunities for full participation in society toward social, economic and cultural growth (Albert 2023). Across all stages of economic growth, there is tremendous need for educational reform to address continuous political, social, cultural, scientific and technical developments.

With the rapid development of ICT in the 1990s, people started to pay more attention to its impact on social development. The term ICT application came into being and began to be popularized (Jaman and Biswas 2025). Various nations have aggressively supported the integration of ICT in education to increase both access and quality. In parallel, the advent of globalization and the move to knowledge-based economies have underlined the need for education institutions to enhance individuals' capacity to apply information in developing, real-world situations. ICT has been regarded as an essential tool in accomplishing these goals (Anon 2003).

ICTs which encompass radio and television, as well as more recent digital technologies like computers and the Internet, have been emphasized as potentially effective enabling instruments for educational reform and change. According to Habib (2017), ICT is an information resource which offers a wide range of materials from around the world to the user. The availability of numerous online information resources from computer files, library catalogues, databases, organizations, newsgroups, industrial and commercial source, as well as from individuals, makes the ICT an indispensable tool for

academia and research (Buabeng et al 2016). Various ICTs are purported to enhance educational quality, expand access to education, reinforce the relevance of education to the increasingly digital workplace and transform teaching and learning into an engaging, active process that is connected to real life when used appropriately (Umunnakwe and Sello 2016). Moreover, ICT is an effective tool, which overcomes the issues of cost, less number of teachers and poor quality of education as well as to overcome time and distance barriers (McGorry 2002).

According to Bindu (2016), ICT also influences the way students are taught and how they learn as now the processes are learner driven and not the teacher driven. However, the experience of implementing different ICTs in the classroom and other educational settings all over the globe over the past few decades reveals that the full realization of the promised educational benefits of ICTs is not automatic.

But it has been determined that the successful integration of ICTs into the educational system is a multifaceted, intricate process that encompasses not only technology, but also curriculum and pedagogy, institutional readiness, teacher competencies and long-term financing, among other factors such as basic education for all, core work skills for all and lifelong learning for all (Suresha and Narayanaswamy 2017, Moges 2014, Tak 2013).

Consequently, educational systems worldwide have a significant amount to contribute in terms of demonstrating the path to enhance the integration of new information and communication technologies (NICTs) into the teaching and learning process, thereby, equipping students with the knowledge and skills necessary for the 21st century (Bingimlas 2009).

Integration of ICT tools in agricultural education

A variety of ICT tools can be integrated into agricultural education to enhance instructional effectiveness. Salehi and Salehi (2012) noted that many ICT applications can support teaching and learning, with some specifically developed for educational purposes and others originally designed for general use. Examples of ICTs that can be employed in agricultural education to support instruction include:

E-learning: E-learning is the effective learning process created by combining digitally delivered content with (learning) support services. E-learning consists of the transfer of skills and knowledge using electronic applications and processes. This may include web-based learning, computer-based learning, virtual classrooms and digital collaboration, use of audio or video recording, satellite or land-based broadcasts, CD-ROM and even the phone system (Blezu and Popa 2008).

Social media: Social media platforms encompass a diverse array of mobile and web-based services that bring people together to engage, communicate, discuss and converse in an online community, exchanging thoughts and data (Panigrahi et al 2024). These are platforms that facilitate social interaction and allow users to easily create and share content (Ibezim 2017). The term social media refers to digital technologies that promote user involvement and information exchange. Platforms like Facebook, blogs, WhatsApp, Instagram and Google Plus may be used effectively in agricultural education to assist learning and communication.

According to Ibezim (2017), there are several ways teachers can utilize social media to enhance agricultural education, including post-course notifications and relevant news updates on blogs, organize seminars and facilitate in-class debates through blog platforms, share records of their own research efforts as reference materials for students, offer commentary on published research within the field, serving as a continuously updated reading resource for students and provide explanations of related topics supported by relevant anecdotes that illustrate real-world implications.

Computer assisted instruction (CAI): CAI utilizes computers directly as a medium for delivering instruction and information. According to Egbuna and Opone (2005), CAI is an instructional design in which the computer system delivers teaching by allowing learners to interact with specifically programmed course content.

Egbuna and Opone (2005) identified three stages of CAI as follows:

Practice and drill level: This represents the most basic level, where learners have already been

introduced to a concept or skill in agricultural education. At this stage, the focus is on reinforcing and refining previously acquired knowledge, skills or processes to enhance mastery.

Tutorial level: At this level, the computer functions effectively as the teacher, assuming the role of the agricultural education instructor. The tutorial stage delivers direct instruction by introducing new concepts and principles. Once the student demonstrates clear understanding, the system promptly advances them to the next activity.

Dialogue level: This is the highest level, involving complex interaction between learners and the computer. Agricultural students actively engage in dialogue with the computer, participating in dynamic, real-time interactions.

Use of computer software/applications: Certain computer software has been created which may be incorporated in agriculture education system for superior instructional delivery. The functionality of the programme depends on the kind. Some examples of such computer software include: Microsoft Power-point, spreadsheet suite (Excel), assessment tools and analysis software (eg SPSS) among others. For instance, power point may be utilized for simple presentation of lesson; spreadsheet package-to-aid learners in calculations while SPSS is employed for easy analysis of study data.

Internet: The Internet is a global network connecting millions of computers through international telecommunications systems (Egbuna and Opone 2005). It provides widespread access to information and resources, making it a valuable tool for education and learning (Ikekeonwu 2003). Teachers can update their knowledge and materials online while students can complete assignments, advance their studies and stay informed through Internet use.

Background

After reviewing the literature from various nations about the use of ICT in agricultural education, as well as the obstacles and strategic solutions for improving its integration into educational systems, a critical analysis is conducted. Tusbira and Mulira (2004), in their study on ICT integration in higher education institutions drawing on experiences from Makerere University and other organizations, found that the infrastructure supporting higher education in Africa is both underdeveloped and unevenly distributed. Moreover, main obstacles experienced by the respondents include lack of understanding and perspective, a systematic way of ICT implementation, cost of bandwidth, lack of top-level commitment for the advancement in ICT integration and for its optimal exploitation. To tackle these issues, they proposed that it is vital to create carefully designed ICT policy for successful collection of funding. Despite these limitations, a substantial number of higher education institutions in Africa have made great progress in constructing an ICT infrastructure and developing computer science and other ICT fields.

Peeraer and Van Petegem (2010) identified key factors influencing the integration of ICT into teaching practices within teacher education institutions in Vietnam. They highlighted that successful adoption of ICT in teaching and learning depends on confidence in using computers, ICT skills and the availability of adequate infrastructure including both hardware and software. They also mentioned hurdles for the adoption of ICT including age of instructor, gender, lack of technical assistance, lack of enthusiasm and insufficient expertise. Authors also mentioned that passionate character of teacher towards the utilization of ICT, budget, educational administration, ICT policies and competent training plays a crucial part in the integration process of ICT.

Wee and Bakar (2006) shed light on the barriers to using ICT tools in information systems education in Malaysian universities. They discovered that the biggest barriers are rapid advancements in ICT tools, inadequate network connectivity, the additional time and effort required to incorporate ICT tools into instruction, inadequate assessment of ICT tool integration in instruction etc. They further disclosed that these barriers must be eliminated in order for ICT to be successfully used in higher education. Ozdmemir and Abrevaya (2007) claimed in their study that ICT is lowering costs per student, increasing enrolments, making accommodations for employers and supporting long-term learners. Mostert and Quinn (2009) examined the impact of ICT on teaching, learning and the professional development of academic staff in South Africa. Their study revealed a pressing need for lecturers to effectively integrate ICT into their teaching practices. As technology continues to transform educational methods, academic staff face the challenge of developing strategies to incorporate these tools successfully. Research of Iran's ICT status and

development strategy conducted by Abbasi et al (2008) found that the country's national ICT strategy should take local, cultural and social concerns into much more account. They further stated that the problems of resistance to change stemming from personal, cultural and infrastructure reasons must be addressed in the national IT policy. In order to successfully deploy ICT in higher education, the government must play a key role as a regulator, promoter and diffuser in the information arena.

Snehi (2009) detailed how the use of ICT in education has changed higher education in the nation in terms of fairness, accessibility and quality. In a study on the evolving role of ICT in Kenyan higher education institutions, Shabya (2009) demonstrated how ICT can be used to explore and simulate abstract concepts while promoting self-learning, the capacity to solve complex problems, teamwork and critical thinking. The limitations that influence senior faculty members' views on utilizing ICT in their teaching activities were found by Qudais et al (2010) at Jordanian universities. Lack of desire to utilize ICT for teaching and learning, hardware and software availability, technical skill deficiencies, insufficient and inadequate infrastructure etc are some of the constraints that have been noted. They also said that reorganizations at several levels, including individual behaviours, attitudes and pedagogical levels, are necessary to successfully use technology in a pedagogically relevant way.

According to Nawaz and Kundi (2010), ICT implementation for teaching and learning purposes is significantly influenced by a number of elements, including age, gender, qualifications, perceptions, experience and organizational features. Moreover, e-learning initiatives have been linked to issues with the development, utilization and advancement of e-learning environments at educational institutions for administrative, instructional and learning objectives.

The use of ICT for administration in higher education institutions was noted by Krishnaveni and Meenakumari (2010). This included general administration, payroll and financial accounting, student data administration, staff records management and library systems. A theoretical model was created once the different elements that influenced these functional domains were determined. Oyel et al (2011) emphasized the need for increased government investment in education to address the challenges of e-learning within Nigerian universities. They also advocated for enhanced training, motivation and awareness programmes to support the effective implementation of e-learning in higher education. There is a need to anticipate the evolving role of technology in education and to undertake appropriate measures to prepare stakeholders for its effective and optimal use (Srivastava et al 2014).

According to Pegu (2014), ICT-enabled education has the potential to revolutionize higher education in India and will eventually result in the democratization of education. ICT is considered a powerful tool for educational change and reform (Boruah 2022).

Research on ICT usage patterns among CCS Haryana Agricultural University students was done by Malik (2019) and reported that the ICT tools were used at a medium level. The author also listed the main barriers that prevent students from using ICT, such as a lack of training resources, lack of experience using ICT and sluggish Internet or server failure. Regarding recommendations, the author recommended using ICT for instruction followed by a better Internet connection.

Mulimani and Naikar (2022) conducted a study on the role of institutions, teachers, students and technology in teaching and learning. They found that before the advent of information technologies, teaching, learning and research in India were conventional or traditional that is an interaction between the teacher and the students and that the library was the primary source of information available at the time, with all of its associated issues (such as a lack of professional staff, outdated materials, staff members who didn't care, theft and mutilation of the resources that were available, among others). This knowledge-gathering and provision method was constrained by geographical and content constraints. The majority of the difficulties associated with teaching and learning are, however, progressively becoming less significant as a result of the development of new technologies, particularly for educational institutions, instructors and students who have benefited from them.

A positive outlook on the integration of ICT in education

ICTs represent a powerful resource with significant educational potential across a wide range of users including primary, secondary and upper secondary as well as individuals seeking career advancement and working professionals (Nagda and

Motwani 2018, Patra 2014). The incorporation of ICT in education has led to considerable advances in both student learning outcomes and teaching approaches (Cunska and Savicka 2012). According to research, learners who use ICT tools frequently perform better academically than those who do not, since ICT serves as an effective support mechanism in the learning process. It facilitates faster and easier access to comprehensive and up-to-date information. Furthermore, ICT can assist in managing complex tasks and provides a reliable platform for scholars to disseminate research findings and academic publications (Adeoye et al 2013, Yusuf 2005).

Three primary rationales for the integration of ICT in education were proposed by Culp et al (2003). The claim was made that ICT is a fundamental factor in economic competitiveness, a change agent and an instrument for resolving issues in the teaching and learning environment.

ICT has the potential to revolutionize the content, methodologies and overall quality and quantity of teaching and learning, thereby, reducing the burden of teachers and ensuring an inquiry-oriented classroom. Furthermore, it is a fundamental force in economic and social transformations that possesses technological proficiency which is essential for the future employment of today's student.

Role of technology in education is quickly emerging as one of the most significant and frequently discussed topics in modern education policy. If ICT is used appropriately, it has the potential to enhance education and shape employment opportunities (Sajuyigbe et al 2013). The government of India have also acknowledged the use of ICT for teacher preparation.

Numerous initiatives are underway to expand the availability of high-quality educational materials in India. These include the Sakshat Portal of the Government of India, the Multimedia Educational Resource for Learning and Online Teaching (MERLOT) and the National Programme of Technology Enhanced Learning (NPTEL). These initiatives aim to create high-quality digital content for various educational levels (Pallavi et al 2013).

According to Shende and Reddy (2020), the main advantages of ICT in education for the various stakeholders are given in Table 1.

Constraints faced in integrating ICT in agricultural education

While the integration of ICT in agricultural education offers numerous benefits, several constraints continue to hinder its effective implementation in agricultural education. Key barriers include unreliable power supply, poor Internet connectivity, inadequate funding, high costs of ICT infrastructure and limited ICT proficiency among some educators. However, Mbodila et al (2013) provided a detailed classification of these challenges into three main categories as follows:

Environmental barriers: In developing nations like India, it is still impractical for people to work, learn and study whenever and wherever they choose. There is insufficient infrastructure to fully integrate ICTs into the classroom. There are inadequate computers, computer laboratories, a weak network and power outages among other things.

Cultural barriers: Another obstacle to integrating ICT in education is cultural diversity throughout the globe. The common vernacular on the Internet is English. According to research, around 80 per cent of content on the Internet is in English. The vast majority of educational software produced for the global market is also in English language. The use of ICTs in agricultural education is significantly hampered in countries like India where English is not the predominant language.

Educational barriers: Reconciling educational goals with economic realities is one of the main issues with ICT integration in the classroom. ICTs in education require significant financial investments. Due to financial constraints, the government of many parts of the world, particularly developing nations, prioritizes teacher welfare and school building restoration. However, ICT for education has not yet been acknowledged as a priority. The dearth of qualified teaching personnel and educators' reluctance to use and integrate ICT as an instructional tool are the main causes of the limitations in terms of human resources.

Strategies to strengthen the integration of ICT in agricultural education (Fig 1)

A major advancement of ICT in education is improved access to learning materials as reported by Adu and Olatundun (2013) reducing reliance on physical libraries and on-site presence of students and teachers.

Table 1. Main advantages of ICT in education for the various stakeholders

Stakeholder	Benefits
Students	Strong understanding of foundational concepts
	Access to insights from experienced subject matter experts
	Ability to store and retrieve large volumes of information digitally
	No risk of missing important classroom discussions
	Open to learners of all age groups
	Eliminates the need for costly textbooks
	No physical attendance at an institution required
	Flexibility to learn at one's own pace and schedule
	Freedom to choose preferred subjects or courses
	Affordable and cost-effective education options
Teachers	Improved effectiveness in content delivery
	Efficient dissemination of information to a large and geographically dispersed student base
	Simplified distribution of study materials and lecture notes
	Streamlined processes for learner assessment and evaluation
	Assignments can be easily distributed, submitted and reviewed
	Simplified data management and analysis for academic records
	Enables continuous tracking of individual student progress
Administrators	Eliminates the requirement for extensive physical infrastructure
	Simplifies data management and storage
	Reduces the need for large libraries and on-site facilities
	Enables efficient tracking of curriculum delivery and content coverage
	Streamlines processes for feedback collection, performance analysis and follow-up actions
Universities	Eliminates the need to maintain physical infrastructure
	Enables effective and optimized data management
	Reduces the time, money and human resources required to perform exams
	Enables timely and effective result processing and delivery
	Provides clear, timely and discreet communication with stakeholders
Parents	Effective monitoring of student attendance
	Simplified tracking of academic progress
	Effective communication between parents and educators
Government	All people should have equal access to education
	Reaches students in rural and isolated places
	Supports lifelong learning opportunities
	Encourages skill advancement and professional development
	Ensures fair access to quality education for all students

Today, ICT has revolutionized this process by making information readily available through digital platforms. Learning resources, including e-books and various online tools, can now be accessed anytime and from virtually any location.

This transformation supports more flexible and efficient teaching and learning experiences. To ensure, ICT is effectively embedded in instructional practices, certain strategic measures are essential.

According to Adu and Olatundun (2013), these include:

Formulate a comprehensive ICT policy for the school: To effectively integrate ICT into the agricultural education, it is essential for school leadership to establish a well-defined ICT policy. This policy serves as a strategic framework, guiding the development and implementation of ICT programmes for both teachers and students in a structured and sustainable way.

Develop proficiency in the technology: Developing foundational skills in word processing, spreadsheets, presentation tools, web navigation and Internet use is essential for strengthening overall computer literacy.

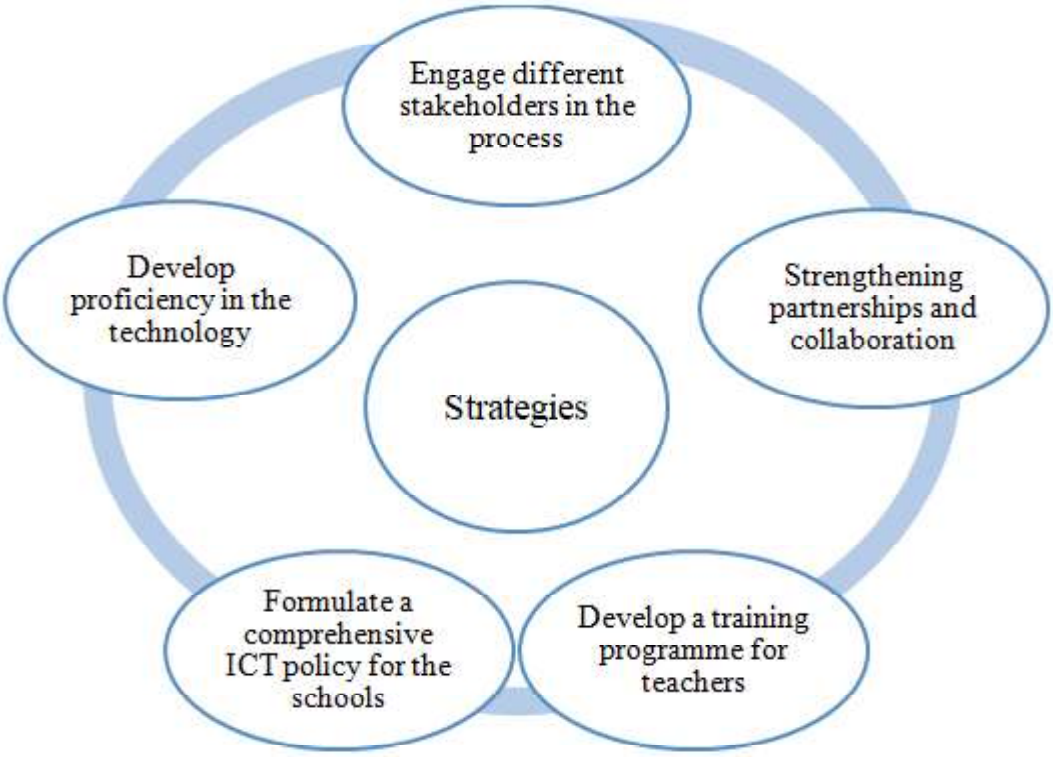

Fig 1. Strategies to strengthen the integration of ICT in agricultural education

To remain competitive and forward-thinking in today's digital landscape, it is crucial to stay current with emerging technologies.

Engage different stakeholders in the process: Participation fosters a sense of ownership and accountability. To ensure the successful implementation of technology, it is important to actively involve all stakeholders in the implementation process.

Strengthening partnerships and collaboration: Fostering strong partnerships and collaborative efforts can significantly support technological advancement and informed decision-making among school leaders. By building effective relationships with the community, public institutions and the corporate sector, leaders can access valuable ICT expertise and secure funding to support technology initiatives.

Develop a training programme for teachers: Teachers play a pivotal role in nation-building and must remain adaptable and proficient with the latest technological advancements. As the primary facilitators of knowledge transfer, ongoing professional development is essential to nurture their expertise. When designing an ICT training programme for educators, the initial focus should be on encouraging their motivation to acquire new knowledge, skills and competencies.

CONCLUSION

The integration of information and communication technologies (ICTs) presents a transformative opportunity to revitalize agricultural education and extension, which is crucial for achieving food security amidst rising global populations and deteriorating natural resources. ICT tools, including E-learning platforms, social media and computer-assisted instruction (CAI), offer substantial benefits: they enhance instructional delivery, democratize access to education, foster critical thinking and problem-solving skills and dramatically reduce the time and cost associated with learning and administration for all stakeholders (students, teachers, administrators and governments). However, the effective realization of this potential is currently hindered by significant and multifaceted barriers. These constraints are categorized as environmental (lack of physical infrastructure, poor connectivity, power), cultural (language dominance of English content) and educational (high initial investment cost, inadequate funding priority and resistance to change among faculty). To secure the

long-term benefits of ICT in agricultural education, a coordinated and strategic approach is essential. This requires: developing foundational technological proficiency across the academic community; formulating a comprehensive, mandatory ICT policy; securing dedicated financial support and implementing continuous professional development and training programmes for teachers to ensure pedagogical relevance. By addressing these infrastructure and human factors, educational systems can successfully leverage new information and communication technologies (NICTs) to equip students with the necessary 21st century skills and drive sustainable agricultural development.

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