

Review

Digital Agriculture Policies and Strategies for Innovations in the Agri-Food Systems—Cases of Five West African Countries

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Abstract: The digital transformation of agriculture can support economic growth and food and nutrition security in Africa. The objectives of this study were to provide an overview of the status of digital agriculture in five West African countries, analyze their efforts in developing the enabling environment and innovations, and formulate recommendations based on the identified gaps for the effective transformation of the sector. For this purpose, a literature search was performed using various sources, including web pages and databases of national agricultural and digital transformation institutions and start-ups of the five target countries (Benin, Burkina Faso, Côte d'Ivoire, Ghana, and Nigeria) and regional/international institutions. The information retrieved was used for individual country and cross-country comparative analysis of the progress and propositions of feasible actions for improvements. The results showed increasing agri-digital initiatives in the five countries, which were grouped into seven categories based on their objectives. Steady progress was also observed in mobile internet adoption, despite the differences in deploying crucial infrastructure to promote digital agriculture. The mobile connectivity index (MCI) in all five countries is below 60. Nonetheless, Ghana and Côte d'Ivoire demonstrated more efforts in internet and electricity access, especially in rural areas. Benin and Nigeria have developed separate documents depicting the roadmap for digital agriculture, while the other countries are working to create one or have it embedded in their national development plans. Similarities and specificities exist among countries for laws and processes protecting agri-digital innovators. To be competitive and self-reliant in the global e-economy, these countries must reposition themselves to accelerate changes in digital agriculture through effective governance and synergy of actions in different sectors and across nations.

Keywords: industrial revolution; digital; agriculture; smallholder farmers; innovations; Africa



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1. Introduction

There are increasing advocates to develop needs-driven innovations to transform the agricultural sector in developing countries facing the challenges of food and nutrition insecurity. Therefore, digital agriculture has emerged as one of the solutions embraced by these countries to achieve their agricultural transformation. Digital agriculture refers to digitizing the different aspects of the farming value chain. Digital agriculture uses computer and communication technologies to provide farmers with information, services, and new opportunities to increase profitability and sustainability in agriculture [1,2].

The digital transformation of agriculture is driving changes in traditional farming, which creates opportunities for farmers and improves the functioning of agri-food systems.

Digitization strengthens the linkages between actors of the agri-food systems, improving access to markets, farm transparency and logistics, and agricultural productivity [3,4]. In addition, farmers have access to inputs and timely technical and weather information, improving their competitiveness. Thus, digital agriculture is an innovative response to the problems of the global food system [5]. Notably, digital agriculture in developing countries has been pivotal in responding to the disruptive impacts of the COVID-19 pandemic on the worldwide agri-food systems [6,7]. During the pandemic, there was higher reliance on digital consulting, digital agricultural financial services, and digital agricultural e-commerce solutions to support the food production and supply systems [8]. Given this impact, the digital transformation of agriculture can drive national economic growth in developing countries [3].

Agriculture remains a priority sector in most Sub-Saharan African countries. However, these countries differ in their digital transformation, which translates into differences in how they cope with complexity and exploit untapped potential and information. In Africa, digital agriculture is gradually taking off but barely reaching 6% of its potential [9,10]. Nigeria accounts for more than half of the population and more than 65% of West African agricultural production, followed by Ghana and Côte d'Ivoire. These three countries have diversified economies linked to oil wealth or industrial dynamics. In Burkina Faso and Benin, the agricultural sector contributes to about 20% and 30% of the gross domestic product (GDP), respectively. However, in most target countries, millions of people are severely affected by acute food insecurity and do not have access to digital technologies. Therefore, continuous government efforts are fundamental to leveraging the benefits of digital technologies to support sustainable growth in the agricultural sector and subsequently to improve nutrition and food security, livelihoods, and eradicate poverty [10,11].

Recently, a consortium comprised of the International Centre of Insect Physiology and Ecology (ICIPE), the Agropolis Fondation (AF), Gearbox Pan African Network (GB), and the Université d'Abomey-Calavi (UAC Benin) was awarded a project funded by the EU and titled "Accelerating Inclusive Green Growth through Agri-based Digital Innovation in West Africa (AGriDI)" to promote a conducive environment for agri-based digital innovations, especially for women and youth farmers, and to accelerate inclusive green growth in target West Africa countries including Benin, Burkina Faso, Côte d'Ivoire, Ghana and Nigeria. The impacts of such initiatives on the digitalization of agriculture in these countries rely on a clear understanding of the existing situation and the gaps to serve as baselines to monitor and evaluate the changes. However, to date, this information is still very minimal. This knowledge is crucial to help formulate clear recommendations for stakeholders supporting the digitization of agriculture in the target countries.

This study presents an overview of the status of agri-digital innovations, analyzing the progress these countries have made in developing the enabling environment and strategies. It highlights the gaps and obstacles and formulates recommendations for the effective deployment of agri-digital technologies in the region.

2. Methodology

The approach used in this study is summarized in Figure 1. By brainstorming on the problem of interest, we identified and described the key concepts with the theme. This informed the next step in the literature review. Then, a desk review was conducted using the corresponding keywords, followed by scanning the retrieved documents, a comparative analysis of the situation of digital agriculture within and among countries, and the reporting.

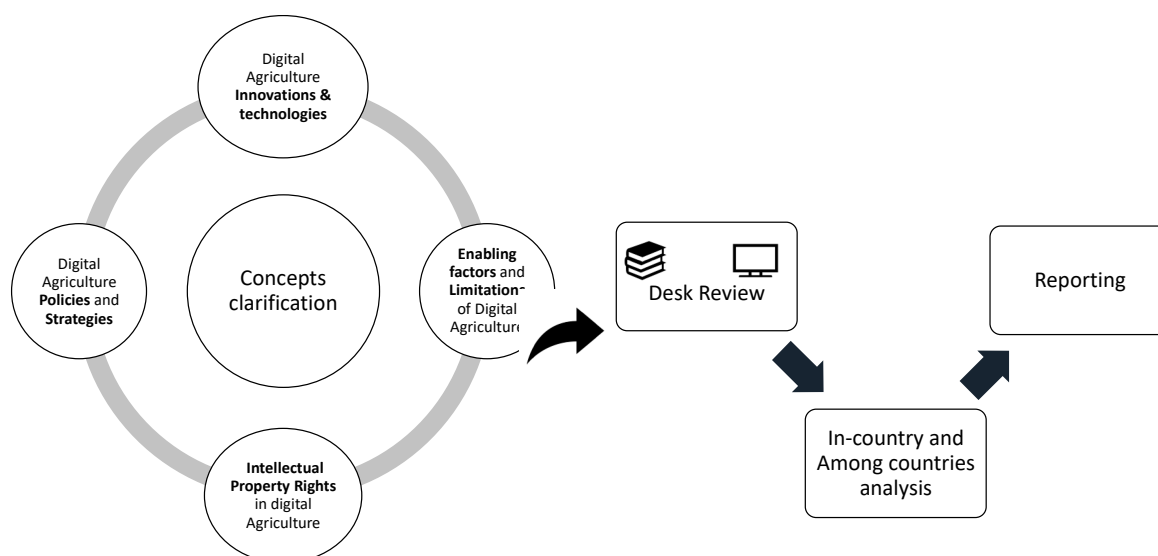


Figure 1. Summary of the approach used in the study.

2.1. Concepts Clarification

In preceptive for a desk review, we first engaged in contextual clarification of concepts. This exercise helped clarify the following concepts related to the problem under study: (i) agri-digital innovations and technologies; (ii) digital agriculture policies and strategies; (iii) intellectual property rights in digital agriculture; and (iv) enabling factors and limitations of digital agriculture development (Figure 1).

2.1.1. Agri-Digital Innovations and Technologies

The quest for “fulfilment and well-being” has shaped our humanity and remains a crucial driver of creative ideas and solutions to various challenges in life. As such, the transformation of the world around us is achieved through “innovation”, i.e., new ideas, goods, and services with the overarching goal of growth. Kahn [12] highlighted that innovation could be understood from the triple dimensions of “outcome–process–mindset”. Applied to digital agriculture, innovation can refer to any outcome resulting from steps or a series of actions anchored on communication technologies that help address the challenges in the agri-food systems [2,3] and is fully acknowledged as such, whether at organizational, institutional, or community levels. These technologies integrate methods and tools [13] that transform the way actors in the agricultural sector access information, goods, and services for value chain development and to increase agriculture’s contribution to economic growth.

Therefore, we adopted in the context of this work “agri-digital innovations and technologies” initiatives that use and/or promote communication technologies to deliver information, goods, and services in the agricultural sector in the target countries.

2.1.2. Digital Agriculture Policies and Strategies

According to Estrada [14], policy is a theoretical or technical instrument formulated to solve societal problems. In this regard, a policy is paramount to create changes across development sectors, including agriculture. In digital agriculture, policies can be referred to as the instruments that promote and regulate the use of digital technology for the collection, curation, analysis, and diffusion of farming data, agenda setting, training, and production in the agricultural sector. In addition, they inform “strategies”, that is, the directions for actions to respond to the needs for agrarian digitalization [15]. Thus, we understood and considered “Digital agriculture Policies and Strategies”, all instruments and interventions put in place by target countries to support and regulate the development of digital agriculture. These also include laws, decrees, projects, and programs deployed by governments to develop digital agriculture.

2.1.3. Intellectual Property Rights (IPRs) in Digital Agriculture

IPRs are exclusive rights given to persons over their creations for a certain period (www.wto.org/index.htm, accessed on 8 October 2022). They can drive the market for the developed products and protect innovators so they can benefit from the fruit of their efforts [16]. According to Blakeney [17], IPRs can be an instrument for encouraging investments in technologies and product development in agriculture. This is true for innovations and technologies in digital agriculture as well. Therefore, in this paper, the term IPRs is used about existing initiatives such as laws, treaties, and services emanating from individual country efforts and/or collective efforts to protect creative ideas for the digitization of agriculture.

2.1.4. Enabling Factors and Limitations of Digital Agriculture

Enabling factors are forces that facilitate changes [18]. In digital agriculture, these factors may refer to elements such as infrastructures and institutional and legal environments that directly or indirectly favour the development and effective use of communications technologies to address challenges in the sector. Hence, we analyzed these factors in this study regarding opportunities and limitations for agri-digital innovations deployment among the target countries.

2.2. Research Design

A literature search was conducted using different search engines: Google Scholar, Web of Science, and Science Direct. Additionally, to gather information, we looked at various sources such as the websites and databases of national agricultural and digital transformation institutions, start-ups in the target countries, and regional/international organizations, including the World Bank, GSM Association (GSMA), International Telecommunication Union (ITU), World Intellectual Property Organization (WIPO), Technical Centre for Agricultural and Rural Cooperation (CTA), International Institute of Tropical Agriculture (IITA), Food and Agriculture Organization (FAO), Alliance for a Green Revolution in Africa (AGRA), United Nations, African Union, West and Central African Council for Agricultural Research and Development (CORAF), Economic Community of West African States (ECOWAS), African Development Bank (AfDB), and World Trade Organization (WTO). Information was retrieved from these sources based on the keywords of the clarification of the concepts described in the previous section: “agri-digital innovations”; “agri-digital technologies”, “e-agriculture”, “(digital agriculture or e-agriculture) policies”; “(digital agriculture or e-agriculture) strategies”; “(digital agriculture or e-agriculture) and intellectual property rights”. The names of the five target countries and the “West Africa” sub-region were used to refine our search further. Moreover, data from the Mobile Connectivity Index, internet use rate, and electricity access of individual countries were sourced from G.S.M.A. [19], World Bank [20], and the Energy Progress Report [21], respectively. The search results were screened for relevancy via a thorough scanning of their contents concerning the key concepts and served as the basis for individual country effort analysis and comparative cross-country analysis. This enables a better understanding of the environment of digital agriculture to formulate recommendations for accelerating its development in the region.

3. Results

3.1. E-Agriculture Initiatives in the Five Countries

In the five target countries, there are increasing agri-digital initiatives. These initiatives are either supported by the public or private sectors or result from a public–private partnership. They include projects or programs and solutions proposed by start-ups. Based on their objectives, they fall into one or more of the following seven categories (Table 1): (i) market information and e-commerce; (ii) digital agricultural advisory and management services; (iii) linkages of value chain actors; (iv) development of key enabling factors;

(v) weather/climate information; (vi) capacity building and training; and (vii) agricultural inputs supply.

Table 1. Some existing agri-digital initiatives in the target countries.

Objectives	Country	Projects/Programs	Start-Ups/Platforms
Market information and e-commerce	Benin	Communal Approach for Agricultural Market (ACMA2) [22] The Digital Rural Transformation Project [23] Project for the Strengthening of Private Sector Actors (PARASEP) [24]	AgriLeap [25] Jinunkun SARL [26] M-Agri [27]
	Côte d' Ivoire	"e-agriculture" project	The platform Buy from Women "Blaatto" [28] ICT4Dev start-up [29,30]
	Ghana	e-agriculture Programme [31]	TechShelta [32] Agro Innova [33] TradeNet.biz [34]
	Nigeria	The national e-agriculture web portal (NEAWP) [35]	
Digital agricultural advisory and management services	Côte d' Ivoire	Project for Disenclavement and e-agriculture (PSNDEA) [36]	ICT4Dev startup [29,30] Wi-Agri [37]
	Benin		Jinunkun SARL [26] Tic-Agro Business Center [38] CEPACC [38]
	Burkina Faso		Cocorico call center [39] Ouaga Lab [40]
	Ghana	e-agriculture Program [38]	TechShelta [32] Esoko [41] Agro Innova [33]
	Nigeria	AgrIDS [42]	
Linkages of actors of the value chain	Burkina Faso		Agri -Yaar [43] Yam Pukri [43]
	Ghana		TechShelta [42]
	Nigeria	The national e-agriculture web portal (NEAWP) [23]	Livestock247 [44]
Development of key enabling factors (roads, Internet infrastructures, electricity, etc.)	Benin	The Digital Rural Transformation Project [23]	
Weather/Climate Information	Côte d' Ivoire	PSNDEA [36]	
Capacity Building and Training	Benin		ICT4AGR-Bénin [45]
	Burkina Faso		Yam Pukri [43] Farafina Agri-Funding [46]
	Ghana	e-agriculture Program [31]	Agro Innova [33]
Agricultural inputs supply	Ghana		Cowtribe [47] TROTRO Tractor Limited [48] Agro Innova [33]
	Nigeria	Growth enhancement support scheme (GESS) [49]	Afrimash [50]

3.1.1. Agri-Digital Projects and Programs

❖ Benin

The Benin government has recently launched different programs and projects to develop e-agriculture in the country.

ACMA 2: The Communal Approach for Agricultural Market Phase 2 (for “*Approche Communale pour le Marché Agricole phase 2*” in French; ACMA 2) was designed to benefit rural actors [22]. The program uses ICT solutions to manage the identification of actors in the agricultural chain for networking, the collection of market information (SIM), e-commerce, the availability of educational content on good farming practices (SIFT), climate forecasts (Ignitia), and the digitization of agricultural financing.

The Digital Rural Transformation Project: Funded by the World Bank [23] through an International Development Association (IDA) credit, contributed to increasing the productivity and competitiveness of agriculture and ICT, identified as important sectors for accelerating economic growth. This project enabled the creation of a platform to promote the value chains of rice, maize, shea, and vegetables. Through this platform, smallholder farmers can access information related to sound production practices, financial services, markets, and sales, which increases their productivity and ability to handle their harvests better. The project has also helped expand ICT connectivity in rural areas. For instance, the fibre optic infrastructure was increased in suburban regions of Parakou.

The Support Project for the Strengthening of Private Sector Actors (PARASEP): Helped develop two information and exchange platforms for actors in the agricultural system in Benin (acteur-agricole.bj and agrizonecna.com), which was launched on 31 March 2021 [24].

❖ Côte d’Ivoire

Project of Digital Solutions for Opening up and e-agriculture: As part of the Digital Solutions of the Project for Reducing Isolation of the Rural areas and e-agriculture (PSNDEA), a digital agricultural platform has been created to provide information on good farming practices through digital means to all remote producers [36].

Project “e-agriculture”: In line with the National Agricultural Investment Program (PNIA) and the government’s strategy for e-agriculture (2016–2019), the “e-agriculture” project was launched to quickly access critical information for their business, including prices on the seed market. The project also provides the Ivorian authorities with reliable data to better manage their policies and strategies favoring agriculture and the rural world [36].

❖ Nigeria

The National E-Agriculture Web Portal (NEAWP): In October 2016, the Federal Government launched the national e-agriculture web portal [23], which aimed to enhance knowledge flow between stakeholders for inclusive development of the agricultural sector. The e-agriculture web portal has also promoted strategic and operational components of Nigeria’s ICT-driven agricultural value chain. To achieve this, the NEAP was designed to bring together all agricultural mobile platforms and applications, both present and future, to produce a single-stop national e-agriculture presence.

Growth Enhancement Support Scheme (GESS): This program has helped improve the delivery of agricultural inputs [49], which has been possible through the use of digital financial services, payment solutions, and by leveraging other levers including quality control and promotion of the private sector’s input value chain.

3.1.2. Digital Agritech Enterprise and Start-Ups

❖ Benin

AgriLeap: This start-up provides agricultural e-advice solutions using drones to capture aerial views of fields. AgriLeap also informs its customers about the suitability of crops to the soils [25].

ICT4AGR-Bénin: Offers training to build the capacity of interested parties in applying digital technologies and sciences to agriculture and related fields [45].

Jinukun SARL [26]: An agritech company that offers agricultural services. It promotes access to agricultural products and local and farm food, improving local farmers' living and working conditions.

❖ Burkina-Faso

Cocorico call center: Allows breeders to access information (produced by satellite imagery) on transhumance corridors, the state of pastures and water points, and veterinary care [39].

Agri-Yaar: This web and mobile platform connect rural supply to rural demand [43].

Yam Pukri: Offers training, information, support, and advice in information and communication technologies [43]. It deploys initiatives in managing agricultural value chains and management of cooperatives: members and Android application for training in cereals (production, conservation, etc.).

Farafina Agri-Funding: A social enterprise working through a digital crowdfunding platform to equip and raise awareness of agricultural entrepreneurship [46].

Ouaga Lab: Has developed "*agri-drone*" to capture the humidity level of the fields and "*agri-alert*" to monitor and send alerts when locusts, armyworms, and seed-eating birds attack fields [40].

❖ Côte d'Ivoire

The platform Buy from Women "Blaatto": A digital platform, cloud-based enterprise, and e-commerce platform offering women information and financials [28].

ICT4Dev start-up: Provision of voice information to the provision of agricultural marketplaces [29,30].

The integrated digital platform Wi-Agri: Answers challenges hampering cashew activity's sustainability. It helps members of the cooperative to map their plantations, reconstruct the path of their products, production to distribution, and, better still, to get paid by mobile money [37].

M-Agri: Provides updated prices of several agricultural commodities, with trends and strategic advice [27].

❖ Ghana

TechShelta: Grants access to advisory, automation, management, training, and market linkages opportunities and inputs for greenhouse production. It helps to remotely control existing manual operating systems such as irrigation, temperature, and humidity using the Internet of Things (IoT) devices [42].

Cowtribe: The start-up helps fight livestock disease by delivering livestock vaccines to rural farmers, tracking the health of each animal, and reminding them when their animals need veterinary services [47].

TROTRO Tractor Limited: Uses the Internet of Things (IoT) and technology to make agricultural mechanization (tractor) service available, accessible, and affordable, enhancing productivity and efficiency and reducing post-harvest loss [48].

Esoko: This platform is designed to help collect full information and to provide digitization tools, analytics, biometric profiling, and communication services [41]. This start-up is a handy tool for digitizing agricultural supply chains, inventory or impact tracking, GIS mapping, or engaging and providing communities with agronomic advisories, climate-smart contents, weather, nutrition, or market information [41].

❖ Nigeria

TradeNet.biz: An online tool for exchanging and managing market information [24].

Afrimash: A digital platform that links farmers to quality inputs. The online platform displays information on different farming product categories, such as poultry, fish, livestock, crops, farm inputs, and farm equipment, which the users can purchase [50].

Livestock247: A multi-stakeholder (buyers, sellers, ranchers, merchants, veterinary professionals, butcheries/abattoirs, logistical services, and financial service providers) platform [44]. For sales of healthy cattle, the platform integrates a unique traceability system that lowers the risk of zoonoses. Additionally, it established markets for wholesale and retail meat sales with full traceability and safety.

3.2. Digital Agriculture Policies and Strategies among the Five Countries

The ability to use digital technologies in agriculture depends on access to basic connectivity infrastructure (broadband, telecommunication services, etc.), data collection, analysis services, development, and the regulatory environment [51]. In this section, we present the status of key enabling factors, including policies and regulations for the smooth and increasing deployment of digital technology into agriculture in the five target countries.

3.2.1. Status of Mobile Connectivity for Developing Digital Agriculture

An overview of the Mobile Connectivity Index (MCI) [19] indicated steady progress (Figure 2) in key enablers of mobile internet adoption (infrastructure, affordability, consumer readiness, content, and services) in all five countries. However, the MCI in the five countries reflects the trends reported in the West Africa region [52], with an MCI below 60, suggesting that a significant gap exists. Ghana and Nigeria have the highest MCI, followed by Côte d'Ivoire, Benin, and Burkina Faso. In contrast, a commitment to increasing mobile internet adoption is observed in Benin and Burkina Faso, with an increase of 12.5 and 8.34 points in their MCI, respectively, between 2017 and 2021 compared to approximately 7.7 points in other countries (Figure 2). Similarly, all the countries exhibit yearly increased internet use rates. Internet use rate [20] in Benin and Burkina Faso is below the average rate in SSA (30%), while Ghana and Côte d'Ivoire keep pace with the world average (60%) (Figure 3).

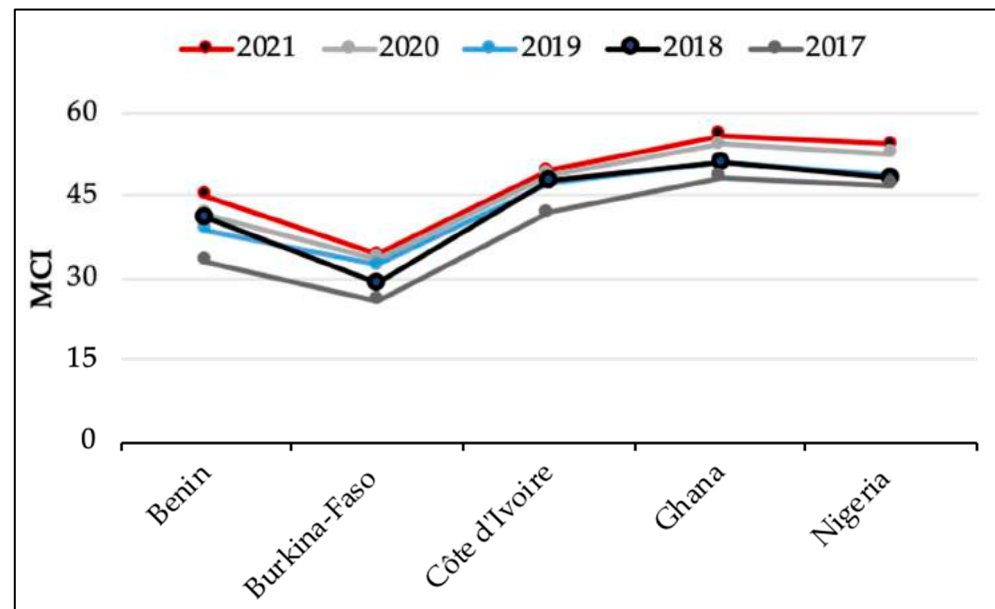


Figure 2. The trend in Mobile Connectivity Index [19] (MCI) in the five target countries.

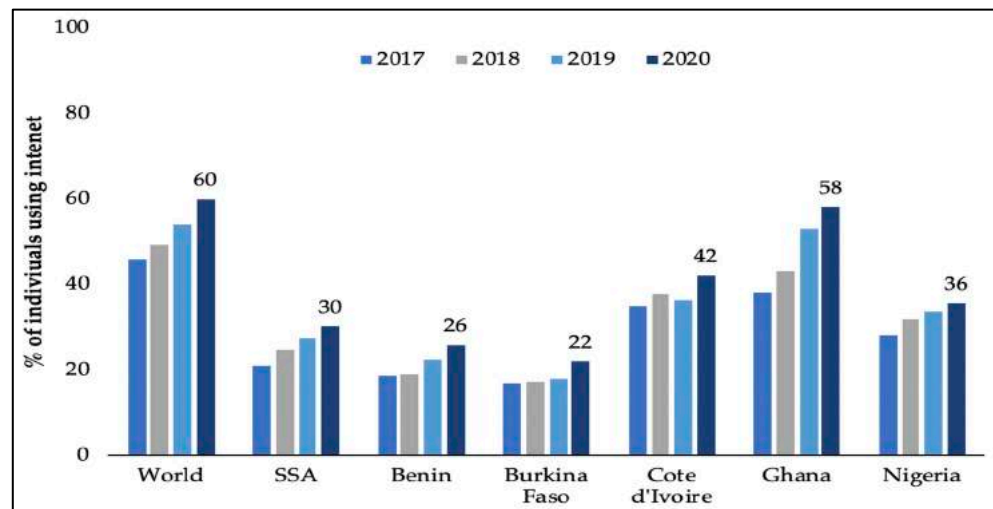


Figure 3. Internet use rate [20] in the five target countries.

3.2.2. Electricity Access Rate in the Five Countries

In terms of infrastructure, electricity is crucial for the swift deployment of digital agriculture. According to the Energy Progress Report [21], above 50% of the population in Ghana, Côte d'Ivoire, and Nigeria have access to electricity, more than in Benin and Burkina Faso (Figure 4). Most of these people, however, live in urban areas, with low access to electricity in rural areas in all target countries except Ghana (74%) and Côte d'Ivoire (42%).

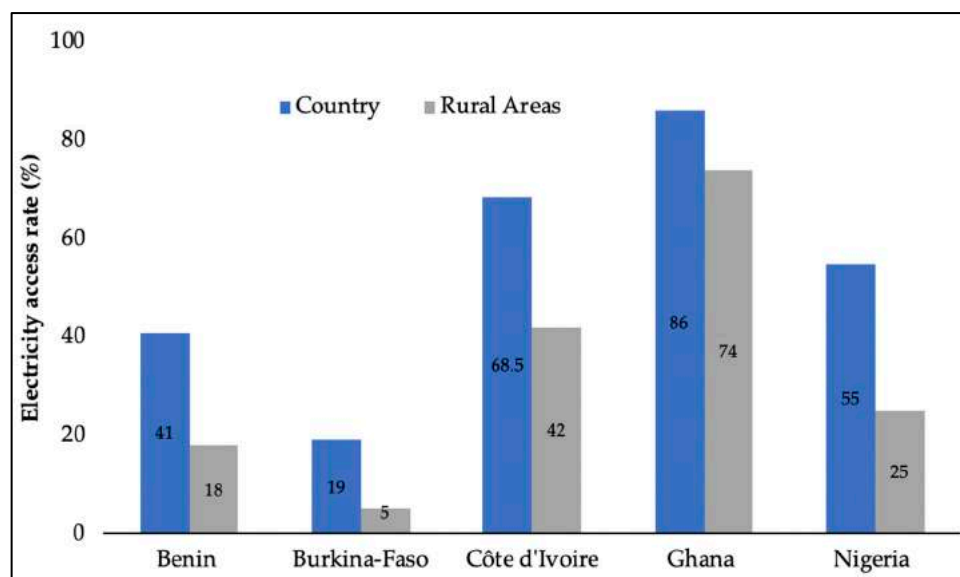


Figure 4. Electricity access rate [21] in the five target countries by 2020.

3.2.3. Status of the National Digital Agriculture Strategy in the Five Countries

The differences in the development of crucial infrastructure among the target countries, as previously described, resulting from the individual country's efforts to promote a conducive environment, including policies and regulations for digital agriculture. A comprehensive national strategy can ensure that e-agriculture projects are not implemented in isolation and leverage efforts and resources to generate practical gains through intra-sector and cross-sector synergies [53]. A country-based analysis revealed that all five countries acknowledged the need for a digital economy and are working to develop different strategic documents (Table 2). Benin [54] and Nigeria [55], in addition to other documents on digital economy policies and regulations, have developed separate documents depicting

the roadmap for digital agriculture. The other countries are either working to establish one or have it embedded in their national development plans (Table 2).

Table 2. Status of the national digital agriculture strategy in the five target countries.

Countries	Recognizing the Need for Action	Formulating the Plan	Validation Phase	Implementation Phase
Benin	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Burkina Faso	<input checked="" type="checkbox"/>			
Côte d’Ivoire	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
Ghana	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Nigeria	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>



Indicates the step is complete or underway.

❖ Benin Policies and Strategies for Digital Agriculture

In Benin, the strategy and development of digitalization are led by the Ministry of Numeric and Digitalization (Ministère du Numérique et de la Digitalisation, MND) in collaboration with agencies such as the Electronic Communications and Postal Regulatory Authority (ARCEP), the Beninese Agency for the Universal Service of Electronic Communications and Post (ABSU-CEP), and the Digitization and Digital Agency and Services and Information Systems Agency.

The country’s agricultural policy is implemented through the “Plan Stratégique de Développement du Secteur Agricole—PSDSA”, which defines four intervention axes/pillars closely linked with the Government Action Program [56,57]. Through its Action Program 2016–2021, the Benin government aspires to position Benin as a digital service platform for West Africa that will accelerate growth and promote social inclusion by 2021. Since 2019, the Benin government has begun mainstreaming digital agriculture into national agriculture development, including developing the national digital agriculture strategy [58]. The political framework of this strategy is anchored in four specific axes: (i) improving governance and information systems for the agriculture, food security, and nutrition sector; (ii) establishing an e-agriculture governance entity that will oversee the implementation of the e-agriculture strategy; (iii) strengthening the existing framework of key policies, legislation, regulations, and guidelines for e-agriculture and ensure its effective implementation; and (iv) establishing an agricultural information system for monitoring and evaluation [58].

The government has deployed an inclusive approach involving government representatives and other key stakeholders to ensure that gaps in capacity building for e-agriculture are identified based on the state of ICTs and the needs on the ground [54]. Among the various reforms in this sector is the creation of the Direction of Information Systems within the Ministry of Agriculture, Livestock and Fisheries (MAEP)—the agricultural digitalization [10] to promote the digitization of farming activities. In addition, the new Drone-Assisted Land Mapping for Climate Smart Cashew Production initiative was launched to support farmers in adopting climate-smart agriculture drone technology [10].

❖ Burkina-Faso Policies and Strategies for Digital Agriculture

In Burkina Faso, the Ministry of the Digital Economy and Posts ensures the implementation and monitoring of the government policy for developing telecommunications/ICT, digital economy, and postal services.

Integration of ICTs in the agricultural sector in Burkina-Faso began with the structural adjustment programs of the 1980s–1990s [28]. These experiments focused on market information systems (MIS) designed to improve the link between production and the market and ensure a fair distribution of profits within the sectors. In the decade of 2000–2010,

NGOs, private companies, and producer organizations (POs) gradually became interested in the potential of ICTs for agricultural advice.

In 2018, the Burkina Faso government initiated a national strategy (2018–2027) to develop the digital economy. This strategy supports infrastructure and digital technology development and the transformation of all productivity sectors, including agriculture, the primary source of livelihood and pillar of the national economy [59]. However, the national digital agriculture policy has yet to be developed, suggesting that the country must connect agriculture and ICT industries [10]. The country possesses a climate-smart agricultural investment plan which identifies big data, remote sensing, GPS, barcoding, and blockchain as promising e-technologies for Burkina Faso's rural sector digitalization [53].

❖ Côte d'Ivoire Policies and Strategies for Digital Agriculture

The Ministry of Digital Economy and Post leads the national strategy for digital economy development. In 2012, the National Agency for the Universal Service of Telecommunications (NASUT) was created to implement the country's digital strategy and to spread the use and adoption of ICT [10]. In 2015, the Agricultural Orientation Law was passed, providing a regulatory framework for all agricultural and ICT-related activities [60].

The major development in digital infrastructure in the country was the result of key policy reforms, especially the 2012 Digital Solutions Program for e-agriculture and the Opening of Rural Areas (PSNDEA). The PSNDEA has helped to realign telecommunications laws with regional priority issues and to establish a national strategy for digital solutions in agriculture and rural areas [60]. In addition, the PSNDEA has narrowed the digital divide gap countrywide by offering connectivity in rural areas and digital services to rural people to strengthen their agriculture value chain and the rural regions [10]. Another strategic document is the second iteration of the National Agricultural Investment Plan (PNIA II), which serves as an umbrella for additional public planning and private investment in the agricultural sector and aligns well with PSNDEA in digital agrarian innovation. Specifically, it addresses electronic producer profiling, geolocation projects, and technologies such as GPS, satellites, smartphones, etc. [61].

Some government initiatives include the Agro-Industrial Pole Project in the Bélier region (2PAI-BELIER). The project was launched in 2016 and has supported ICT-led agro-industrial transformation in the central part of the country. Furthermore, in 2019, the government agreed to pay a living income differential for every ton of cocoa sold to review the production and pricing in the farmers' interest and to revitalize digital procurement. As a result, the country was ranked 172 in the UN's E-Government Development Index and the first among the ECOWAS countries [10].

❖ Ghana Policies and Strategies for Digital Agriculture

Implementing policies to improve Ghana's information and communication infrastructure and service delivery is the primary responsibility of the Ministry of Communication and Digitalization, which was established under section II of the Civil Service Law, 1993 (PNDCL, 327) as revised by the Civil Service Act, 2001. Ghana's National Cybersecurity Policy and Strategy, ICT for Accelerated Development (ICT4AD) Policy, National Broadband Policy and Implementation Strategy, and Digital Financial Services Policy are some recent policies enacted to speed up developments in the ICT and telecommunication sectors. Among the policies recently adopted to accelerate results in the ICT and telecommunications sector are Ghana's National Cyber Security Policy and Strategy, the ICT for Accelerated Development (ICT4AD) Policy, the National Broadband Policy and Implementation Strategy, and the Digital Financial Services Policy.

Launched in 2003, the ICT for Accelerated Development (ICT4D) Policy has used ICTs as broad-based enablers of growth development in Ghana. In 2012, a broadband strategy was established to connect broadband policy and universal access policy, which has facilitated access to broadband infrastructure and last-mile connectivity to communities and homes and converged infrastructure and service delivery in agriculture [62].

In 2014, a national cybersecurity policy was enacted, which presents food and agriculture as vital infrastructures and areas needing investment for national economic transformation. A digital agriculture policy, strategic plan, and action plan have also been designed to support e-agriculture development in the country. In addition, the Ministry of Food and Agriculture is working to make agricultural extension and other advisory services accessible to all actors. Moreover, a 10-year Digital Agricultural Advisory Service Strategic Plan has been initiated to spearhead the changes [10].

❖ Nigeria Policies and Strategies for Digital Agriculture

The status of digital agriculture in Nigeria is the result of stepwise progress. Since 1992, the Nigerian government has enacted the National Broadcasting Commission (NBC) Decree 38 and the Nigerian Communications Commission (NCC) Decree 75 brought a steady transformation in the ICT environment. As a result, there has been an increasing interest in the broadcasting and telecom markets [63]. In 2012, Nigeria's Federal Ministry of Communications (FMC) created the country's ICT strategy and developed a communications policy that was implemented by the Nigerian Communications Commission (NCC). In 2015, the Nigeria Communications Commission's (NCC) 8-Point Agenda proposed the transition of Nigeria into a digital economy through investment in digital infrastructure. As a result, Nigeria has become the largest mobile market in Sub-Saharan Africa, powered by robust mobile broadband infrastructure and connectivity, which constitute a significant potential to improve agri-food systems and employment [63].

The National Information Technology Development Agency (NITDA) is mandated to coordinate general IT policies and development in Nigeria [55]. From 2011–2015, the Nigerian government implemented the Agricultural Transformation Agenda (ATA) in the agriculture sector, which introduced business-like processes. Following the ATA, the government launched the Agriculture Promotion Policy (2016–2020) in 2015, anchored in a multisectoral approach, including digital innovations to support agricultural research and farming activities. In addition, the country has recently developed the Nigeria Digital Agriculture Strategy as a ten-year (2020–2030) plan that guides adopting digital technologies in agriculture [55], which could drive significant changes in the agri-food sector.

The government has introduced some policies and programs to enhance local trade and exports. These include the Nigeria–Africa Trade and Investment Promotion Program, the Presidential Economic Diversification Initiative, the Zero Reject Initiative, and the Economic and Export Promotion Incentives. Comparatively, the Economic Recovery and Growth Plan 2017–2020 (ERGP) has supported and encouraged digital entrepreneurship in agriculture. In addition, the government also adopted the Nigeria ICT Road Map 2017–2020 and the Nigeria ICT Innovation and Entrepreneurship Vision (NIIEV), which have created a conducive environment for the use of ICT to diversify business opportunities in agriculture [10,63].

3.3. IPRs and Digital Agriculture

IPRs protect innovators using information and communication technology (ICT) to deliver timely information and services for the development of the agri-food sector. There are similarities and particularities among the five AGrIDI target countries for laws and processes protecting agri-digital innovators. All five AGrIDI target countries are member states of the World Trade Organization (WTO) and, therefore, comply with the Trade-Related Aspects of Intellectual Property Rights Agreement, which sets the obligations for the protection of copyrights, patents, industrial designs, semiconductors, trademarks, and undisclosed information [64]. In addition, these countries are also member states of WIPO, which operates an online platform accessible for innovators from the participating countries to access IPR-related services [65] efficiently.

At regional levels, Benin, Burkina Faso, and Côte d'Ivoire are members of the African Organization of Intellectual Properties (OAPI), which can also assist agri-digital innovators in these countries in the administrative procedures of the standard industrial property

and in the provisions of international conventions (www.oapi.int/index.php/fr/services, accessed on 8 October 2022).

At the country level, the Ministry of Trade and Industry and/or Ministry of Justice and the representations of OAPI and WIPO provide regulations and access to IPR services. Furthermore, agri-digital innovations from public institutions such as national universities are primarily protected by the IPRs [66] of these institutions, and the innovators can also seek international and or regional IPRs to protect their innovations.

❖ Benin

The National Agency of Industrial Property (ANaPI) helps inventors, innovators, and academics to protect their different creations. In addition, ANaPI serves as the WIPO Directory of Technology and Innovation Support in Benin. Created by the decree N° 84-353 of 21 September 1984, the National Center for Industrial Property (CENaPI) was transferred to the National Agency for Industrial Property (ANaPI); endowed with legal personality and financial autonomy by decree N° 2010-262 of 11 June 2010 approving its statutes.

❖ Burkina-Faso

As a member country of the OAPI, Burkina Faso also hosts a National Liaison Structure (NLS) of OAPI [67]. Created in 1982, this service, under the administrative authority of the ministry in charge of the industry, helps to centralize and transmit OAPI applications for the protection of industrial property rights. It also creates awareness among the public about the IPRs and OAPI.

❖ Côte d'Ivoire

The Ivorian Intellectual Property Office (OIPI) is the national public institution created by decree n° 2005 112 of 24 February 2005, in charge of administering the intellectual property system [68]. It also represents the African Intellectual Property Organization (OAPI) and the World Intellectual Property Organization (WIPO).

❖ Ghana

This country is a signatory of the Lusaka Agreement [69] on establishing the African Regional Intellectual Property Organization (ARIPO), which promotes IPRs among its member states. The Ghana Copyrights Office [70] also serves as a representation of the WIPO in Ghana. In 2016, the government launched a National Intellectual Property Policy and Strategy to strengthen the legal framework for the administration, protection, and enforcement of IPR innovation and awareness.

❖ Nigeria

The Copyrights Act, the Patents and Designs Act, and the Trademarks Act are Nigeria's three main statutes [71] governing intellectual property law. In January 2020, the WIPO Nigeria Office (WNO) was established in Abuja to promote awareness and increase training and capacity building in intellectual property (IP) and across WIPO's global services in Nigeria.

Based on the above, it can be stated that in the five target countries, governance of IPRs exists to some extent, including the legal and institutional framework. However, factors such as corruption, lack of enforcement, lack of skilled personnel, and awareness of intellectual property rights are barriers to IPR development [72]. A common trend in many African countries, this situation also slows innovations among these countries compared to countries that have fully embraced e-economy, including e-agriculture, to foster growth. For example, Africa accounted for only 0.5% of global patent applications in 2019, against 66.8% for Asia, 19% for North America, and 10.9% for Europe [64]. Hence, these countries must work quickly to connect the digital sector and agriculture and provide an environment that protects innovators.

4. Discussion

The digitalization of the agricultural sector can help achieve economic growth and food and nutrition security in developing countries. The rapid development of ICTs has revolutionized the African agri-food system creating new opportunities hitherto untapped in all sectors, from production to commercialization of value-added products [73]. Our review of the existing literature revealed that there are increasing efforts from all five countries to develop infrastructures and an enabling environment for digital agriculture. However, there is still a significant gap in electricity and internet access in the rural areas, which requires more engagement from all countries, especially Benin and Burkina Faso. The statistics on enabling agri-digital infrastructures support that the deployment of digital agriculture could be faster in Ghana, Côte d'Ivoire, and Nigeria than in Benin and Burkina Faso. In digital agriculture, mobile phones and the Internet are essential resources for deploying technologies and innovations to enable farmers in developing countries to make informed decisions in their farming activities. Therefore, it is necessary to increase effective mobile penetration and internet usage in response to farmers' needs and the challenges they face to bridge the knowledge and information gaps and provide equitable markets and businesses for expedited development growth in this part of the world [1].

In all studied countries, there is a strong engagement from public and private actors to nurture innovative solutions through different start-ups, platforms, projects, and programs. The various initiatives allowed easy farmers' access to agricultural inputs and markets connecting farmers and consumers. These mobilizations, which varied among the countries, are evolving despite the economic, social, political, and legal challenges. As highlighted by Coggins et al. [74], the most common barriers to full digital extension technology are unawareness, inaccessible mobile networks, inaccessible electricity, inaccessible devices, slow access, unfamiliar language, insensitivity to digital illiteracy, insensitivity to user's knowledge, insensitivity to priorities, insensitivity to socioeconomic constraints, and irrelevance to farm. Factors such as high illiteracy and unawareness of digital technologies among small-scale farmers in the study countries still hamper digital agriculture's full development and adoption. Even if the technologies are developed, they may not be easily adapted to increase farms' performances. This can be resolved by effective policies and synergy of actions in different development sectors to support critical enabling factors, education and literacy, and mainly digital literacy among the youths who are crucial agents of the digital agriculture transformation.

Sustainable and inclusive development of digital agriculture can be achieved by deploying e-policies and e-strategies on e-content, e-trust, e-security, e-value addition, and end-user-driven e-technologies [73]. The analysis of the status of the policies and strategies among the five countries revealed a need for regional harmonization to provide essential guidance to countries to support the development of their e-agriculture strategic plan by promoting integration and sharing of experiences following different regional and international treaties. Most countries still face challenges in creating a favorable business environment [10]. Nevertheless, the review showed that most countries had developed a national strategic plan for e-agriculture. It is, therefore, necessary to execute the plan and monitor the indicators of success while maintaining a window for continuous improvement in the enabling policy and regulatory environment. In line with this, the five countries are members of various regional and international organizations such as WIPO, WTO, OAPI, and ARIPO, which facilitate the enforcement of IPR laws. However, the process leading to the protection of the creation of agri-digital innovators, especially at the country level, is still not well-documented, requiring significant efforts to streamline, document, and disseminate the process of obtaining patents for agri-digital technologies at the country level.

To be competitive and self-reliant in the global e-economy, the five countries must reposition themselves to accelerate changes in digital agriculture. This can be executed through continuous efforts to integrate action along four intervention axes as interconnected parts of a road map to achieve the paradigm shift. These axes are (i) policies and

regulations; (ii) infrastructures (ICT and electricity); (iii) research and innovations for digital agriculture; and (iv) intellectual property rights protecting the developers of agri-digital technologies/innovations (Figure 5).

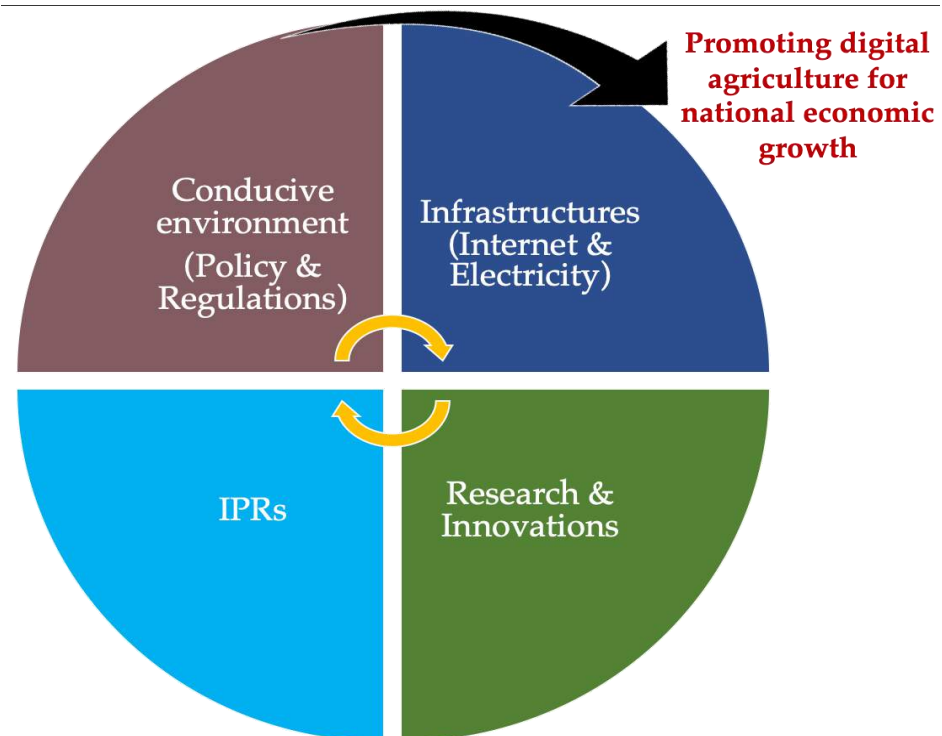


Figure 5. Integrated approach for promoting agri-digital innovations in the target countries.

The five countries should guarantee the enabling environment for digital agriculture development. They should promote interventions and investments for increasing electric power supply and network connectivity, especially in rural areas where most agricultural labor forces are located. It should also be pointed out that these countries should constantly accelerate research and innovations for e-agriculture through strategic investments in academia that will enable the training of more digital agriculture innovators. This may require curricula revisions connecting theoretical learning with hands-on industry experience, strengthening public-private partnerships, and equipping trainees with the skills needed by the job market. Furthermore, the governments of these countries should streamline the practical application and delivery of IPRs for innovations in digital agriculture, increase awareness, and enforce the laws and regulations regarding IPRs.

5. Conclusions and Perspectives

This study examined innovations, policies, and strategies for digitalizing agriculture in five West African countries: Benin, Ghana, Burkina Faso, Nigeria, and Côte d'Ivoire. It has revealed growing interest from both the public and private sectors in the digitization of agriculture in these countries. The existing interventions are developed to provide one of the following seven services: (i) market information and e-commerce; (ii) digital agricultural advisory and management services; (iii) linkages of value chain actors; (iv) development of critical enabling factors; (v) weather/climate information; (vi) capacity building and training; and (vii) agricultural inputs supply. These countries are all making efforts to ensure the development of an enabling environment for digital agriculture. However, differences were observed among them regarding digital infrastructures, policies, and strategies concerning their economic growth, suggesting more sustained commitments to strengthen the sectors' governance.

Similarly, to some extent, there are efforts from these countries to guarantee access to intellectual property rights for agri-digital innovations. Furthermore, the five countries are members of various regional and international organizations which facilitate the enforcement of IPR laws. Inferring on the analysis of the situation in the five countries, we recommend that all countries in the region must accelerate the deployment of electricity and the Internet in rural areas while increasing effective policies and synergy of actions in different development sectors, including digital literacy because they form the foundation of the nation's agricultural system. Regional harmonization is also required to streamline the establishment of national e-agriculture strategy plans by encouraging integration and experience sharing per various regional and international treaties.

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