Preprints.org

Article

Digital Agriculture Policies and Strategies for Innovations in the Agrifood Systems: Cases of five West African Countries

Jules DEGILA [*] , Frejus Ariel Kpedetin SODEDJI , Hospice Gerard Gracias AVAKOUDJO ,
Souand Peace Gloria TAHI , Sèton Calmette Ariane HOUETOHOSSOU , Anne-Carole HONFOGA ,
Ida Sèmévo TOGNISSE , Achille Ephrem ASSOGBADJO

Article

Digital Agriculture Policies and Strategies for Innovations in the Agrifood Systems: Cases of Five West African Countries

Jules DEGILA [1],*, Frejus Ariel Kpedetin SODEDJI [2], Hospice Gerard Gracias AVAKOUDJO [2], Souand Peace Gloria TAHI [3], Seton Calmette Ariane HOUETOHOSSOU [3], Anne-Carole HONFOGA [4], Ida Sèmévo TOGNISSE [1] and Achille Ephrem ASSOGBADJO [3]

[1] Institut de Mathématiques et de Sciences Physiques; Porto-Novo, BP 613, Bénin jules.degila@imsp-uac.org (J. D.); ida.tognisse@imsp-uac.org (I. S. T.)

[2] Non-Timber Forest Products and Orphan Crops Species Research Unit, Laboratory of Applied Ecology (LEA), University of Abomey-Calavi; 01 BP 526 Cotonou, Benin; graciasavakoudjo@gmail.com (H. G. G. A.), frejusariel@gmail.com (F.A.K.S.); achille.assogbadjo@fsa.uac.bj (A.E.A)

[3] Laboratoire de Biomathématiques et d'Estimations Forestières, Faculty of Agronomic; 04 BP 1525 Cotonou, Benin; harianecalmet@gmail.com (S. C. A. H.), souandtahi@gmail.com (S. P. G.T.)

[4] URPHORAN, Laboratoire d'Electrotechnique, de Télécommunications et d'Informatique Appliquée LETIA EPAC, UAC., hacropas@gmail.com (A. H.)

* Correspondence: jules.degila@imsp-uac.org.

Abstract: Digital transformation of agriculture can support economic growth and food and nutrition security in Africa. Here, we provide an overview of the status of digital agriculture in five west African countries, analyzing their efforts in developing the enabling environment and innovations while formulating recommendations based on the identified gaps for the effective transformation of the sector. Information was retrieved through a literature search from 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, Nigeria) and regional/international institutions. There have been 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 Cote 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

1. Introduction

Facing the challenges of food and nutrition insecurity, there are increasing advocates to develop needs-driven innovations to transform the agricultural sector in developing countries. Digital Agriculture has therefore 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. It defines targeted information services as helping farmers to use new technology to increase productivity and profitability [1]. Digital agriculture uses computer and

communication technologies to increase profitability and sustainability in agriculture and brings together new opportunities [2].

The digital transformation of agriculture has many benefits for smallholder farmers, including improved market access, enhanced farm productivity, transparency, and logistics [3]. Digitalization boosts the connectivity of all actors across the agrifood system [4]. It helps farmers access technical information, higher-quality seeds, real-time data which improve their competitiveness. Digital agricultre is therefore an innovative response to the problems of the global food system [5]. Notably, digital agriculture has helped developing countries resist the COVID 19 pandemic's adverse effects on food production and supply chains [6,7]. Digital advisory, agricultural digital financial services and Agri e-commerce solutions were the three most used digital tools by farmers during the pandemic [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,. 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 about 20 % and 30 % of the Gross Domestic Product (GDP), respectively. In most 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 suppport sustainable growth in the agricultural sector and subsequently to improve nutrition and food security, livelihoods and eradicate poverty [10,11].

Recently, a consortium made of the International Centre of Insect Physiology and Ecology (ICIPE), the Agropolis Foundation (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.

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, highlighting the gaps and obstacles to formulate recommendations for effective agricultural sector transformation.

2. Methodology

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 the obtained documents and reports based on the keywords related to the topic of interest, which include innovations/technologies used, the policies and strategies for digital agriculture, the intellectual property rights of Agri-digital innovations, the enabling factors and limitations for the deployment of digital technologies in agriculture in the five target countries.

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 supported by the public or private sector 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 /Programmes	Start-ups/Platforms
Market information and e-commerce	Benin	Communal Approach for Agricultural Market (ACMA2) [12] The Digital Rural Transformation Project [13] Project for the Strengthening of Private Sector Actors (PARASEP) [14]	AgriLeap [15] JINUNKUN SARL [16] M-Agri [17]
	Côte d'Ivoire	"e-agriculture" project	The platform Buy from Women "Blaatto"[19] ICT4Dev startup [20,21]
	Ghana	E-Agriculture Programme[18]	TechShelta [22] Agro Innova [23] TradeNet.biz [24]
	Nigeria	The national e-agriculture web portal (NEAWP) [25]	
Digital agricultural advisory and management services	Côte d'Ivoire	Project for Disenclavement and e-Agriculture (PSNDEA) [26]	ICT4Dev startup [20,21] Wi-Agri [27]
	Benin		JINUNKUN SARL [16] Tic-Agro Business Center [28] CEPACC [28]
	Burkina-Faso		Cocorico call center [29] Ouaga Lab[30]
	Ghana	E-Agriculture Programme [18]	TechShelta [22] Esoko [31] Agro Innova [23]

	Nigeria	AgrIDS [32]	
Linkages of actors of the value chain	Burkina-Faso		Agri -Yaar [33] Yam Pukri [33]
	Ghana		TechShelta [22]
	Nigeria	The national e-agriculture web portal (NEAWP) [25]	Livestock247 [34]
Development of key enabling factors (roads, Internet infrastructures, electricity, etc.)	BENIN	The Digital Rural Transformation Project [35]	
Weather/Climate Information	Côte d'Ivoire	PSNDEA [26]	
Capacity Building and Training	BENIN		ICT4AGR-Bénin [36]
	Burkina-Faso		Yam Pukri [33] Farafina Agri-Funding [37]
	Ghana	E-Agriculture Programme [18]	Agro Innova [23]
Agricultural inputs supply	Ghana		Cowtribe [38] TROTRO Tractor Limited [39] Agro Innova [23]
	Nigeria	Growth enhancement support scheme (GESS) [40]	Afrimash [41]

3.1.1. Agri-digital Projects and Programmes

❖ **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 (Approche Communale pour le Marché Agricole phase 2; ACMA 2) was designed to benefit rural actors [12]. 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 agricultural practices (SIFT), climate forecasts (Ignitia) and the digitization of agricultural financing.

The Digital Rural Transformation Project: funded by the World Bank [13] through an International Development Association (IDA) credit, it contributed to increasing the productivity and competitiveness of two sectors identified as critical enablers of growth, which are agriculture and ICT. This project enabled the creation of a platform to promote the value chains of rice, maize, shea and vegetables. Through this platform, smallholder farmers access information related to good

production practices, financial services, markets and sales, which increase their productivity and to better handle their harvests. The project has also helped expand ICT connectivity in rural areas. For instance, the fiber optic infrastructure was increased in suburban regions of Parakou.

The Support Project for the Strengthening of Private Sector Actors (PARASEP): it 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 [14].

❖ **CÔTE D'IVOIRE**

Project of Digital Solutions for Opening up and e-agriculture: As part of the Digital Solutions of the Project for Disenclavement 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 [14].

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 favouring agriculture and the rural world [14]

❖ **NIGERIA**

The national e-agriculture web portal (NEAWP): The Federal Government launched in October 2016 the national e-agriculture web portal [25]to enhance the knowledge flow between stakeholders and ensure inclusive and robust development of the agricultural sector. It also aims to highlight the strategic and operational components of the ICT-driven agricultural value chain in Nigeria, especially as it relates to the recently launched Green Alternative policy. To this end, the NEAWP integrates all existing and future agricultural platforms and mobile applications to create a one-stop national e-agriculture presence.

Growth enhancement support scheme (GESS): The programme has helped improved the delivery of agricultural inputs   [40]. This has been possible through to the use of digital financial services and payment solutions as well as the leveraging of others levers including the regulation of the quality, promotion of the private-sector input value chain.

3.1.2. Digital Agritech enterprise and start-ups

❖ **BENIN**

AgriLeap: the start-up provides agricultural E-advice solutions using drones to take aerial views of fields. AgriLeap also informs its customers about the suitability of crops to the soils [15].

ICT4AGR-Bénin: it offers training to build the capacity of interested parties in applying digital technologies and sciences to agriculture and related fields [36].

JINUKUN SARL [26]: it is an agritech company that offers agricultural services. It promotes access to agricultural products and local and farm food, improving the living and working conditions of local farmers.

❖ **BURKINA FASO**

Cocorico call centre: It allows breeders to access information (produced in particular by satellite imagery) on transhumance corridors, the state of pastures and water points, and veterinary care [29].

Agri -Yaar : this is a web and mobile platform that connects rural supply to rural demand [33].

Yam Pukri: it offers training, information, support, and advice in information and communication technologies [33]. It deploys initiatives in managing agricultural value chains, management of cooperatives: members, contractualization, and Android application for training in cereals (production, conservation, etc.).

Farafina Agri-Funding: is a social enterprise working through a digital crowdfunding platform to equip and raise awareness on agricultural entrepreneurship [37].

Ouaga Lab: it 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 [30].

❖ **CÔTE D'IVOIRE**

The platform Buy From Women "Blaatto˝: it is a digital platform, cloud-based enterprise, and e-commerce platform offering women information and finance [19].

ICT4Dev start-up: provision of voice information to the provision of agricultural marketplaces [20,21].

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 [27]

M-Agri: provides updated prices of several agricultural commodities, with trends and strategic advice [17].

❖ **GHANA**

TechShelta: It gives 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 Internet of Things (IoT) devices [22].

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 [38].

TROTRO Tractor Limited: it 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 [39].

Esoko: the platform is designed to help collect robust and to provide digitization tools, analytics, biometric profiling, and communication services [31]. The 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 [31].

❖ **NIGERIA**

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

Afrimash: is a digital platform that efficiently connects farmers to quality inputs (e.g., poultry, fish, livestock, crops, farm inputs, and farm equipment) [41]

Livestock247: is a multi-stakeholder (buyers, sellers, ranchers, merchants, veterinary professionals, butcheries/abattoirs, logistical services, and financial service providers) platform [34]. It has a unique traceability system for healthy cattle sales, reducing the risk of zoonoses. It also developed meat sales with complete traceability, safety, and structured markets for wholesale and retail consumption.

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.), the development of data collection and analysis services, and the regulatory environment [42]. 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) [43] indicated steady progress (Figure 1) in key enablers of mobile internet adoption (infrastructure, affordability, consumer readiness, and content and services) in all five countries. However, the MCI in the five countries reflects the trends reported in the West Africa region [44], with an MCI below 60, suggesting a significant gap exists. Ghana and Nigeria have the highest MCI, followed by Côte d'Ivoire, Benin and Burkina-Faso. On the other hand, 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 between 2017 and 2021 compared to approximately 7.7 points in other countries (Figure 1). Similarly, all the countries are increasing internet use rate from year to year. Internet use rate [45] in Benin and Burkina-Faso is below the average rate in SSA (30%), while Ghana and Côte d'Ivoire are keeping pace with the world (60%) (Figure 2).
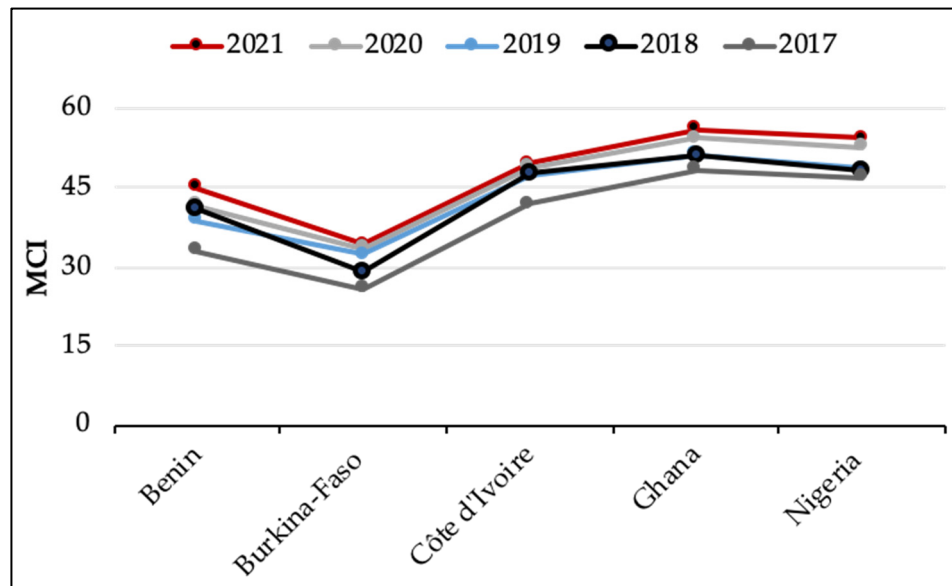
**Figure 1.** The trend in Mobile Connectivity Index[43] (MCI) in the five AgriDI target countries.
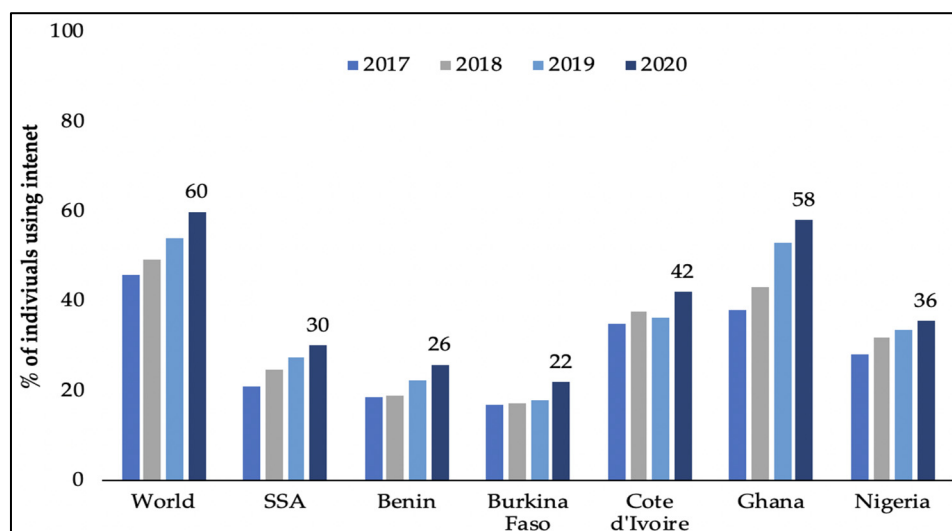
Figure 2. Internet use rate[45] in the five AGrIDI target countries.

3.2.2. Electricity access rate in the five AGriDI target countries

In terms of infrastructure, electricity is crucial for the swift deployment of digital agriculture. According to the Energy Progress Report [46], above 50% of the population in Ghana, Côte d'Ivoire, and Nigeria have access to electricity more than in Benin and Burkina-Faso (Figure 3). The majority 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%).
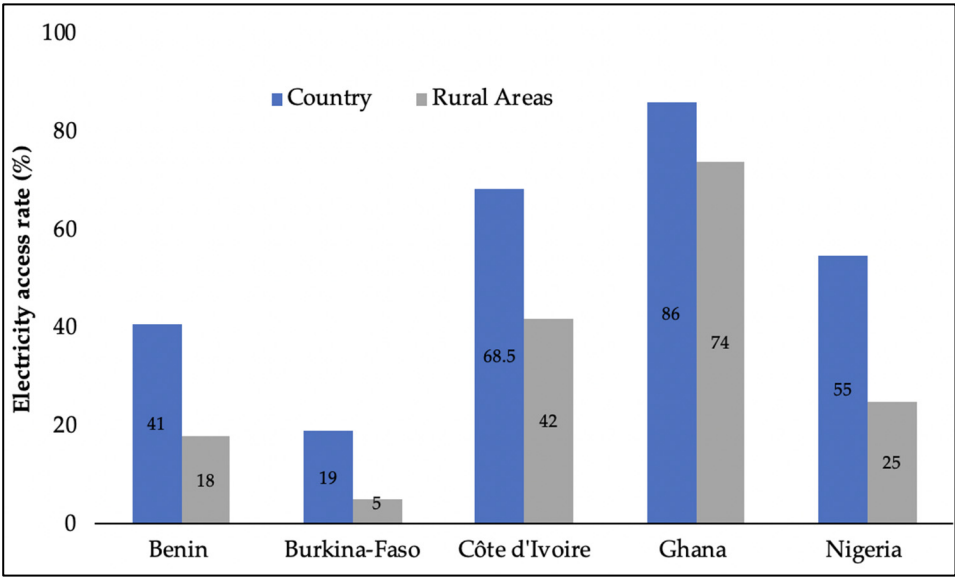
Figure 3. Electricity access rate[46] in the five AGriDI target countries by 2020[46].

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

The differences in the development of crucial infrastructure among the target countries, as described above, result 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, leverage efforts and resources to generate effective gains through intra-sector and cross-sector synergies [47]. A country-based analysis revealed that all five countries acknowledged the need for a digital economy and are working to develop different strategic documents. However, except Benin [48] and Nigeria [49], which 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 develop one or they have it embedded in their national development plans.

Table 2. Status of the national digital agriculture strategy.

Countries	Recognizing the need for action	Formulating the plan	Validation Phase	Implementation Phase
Benin	✓	✓	✓	✓
Burkina-Faso	✓			
Côte d'Ivoire,	✓	✓	✓	
Ghana	✓	✓	✓	✓
Nigeria	✓	✓	✓	✓

✓Indicates the step is done 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), 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 interventions axes/pillars closely linked with the Government Action Program [50,51]. 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 [48]. The political framework of this strategy is anchored on 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.

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 [48]. 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 [52] 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 [52].

❖ **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 [29]. 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 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 [53]. The national digital agriculture policy is still not yet developed, suggesting that the country has to connect agriculture and ICT industries [52]. 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 agrarian sector digitalization [54].

❖ **CÔTE D'IVOIRE policies and strategies for digital agriculture**

The Ministry of Digital Economy and Post champions 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 [52]. In 2015, the Agricultural Orientation Law was passed providing a regulatory framework for all agricultural and ICT related activities [55].

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), which realigned telecommunications laws with regional priority issues and defined a national strategy for digital solutions in agriculture and rural areas [55]. The PSNDEA aimed at reducing the digital divide by providing connectivity in rural areas while providing digital services to rural communities to improve their agricultural value chain [52]. Another strategic document is the second iteration of the National Agricultural Investment Plan (PNIA II), which provides an additional framework for public programming and private investment in the agricultural sector and aligns well with PSNDEA in digital agricultural Innovation. Specifically, it addresses electronic producer profiling, geolocation projects, and technologies such as GPS, satellites, smartphones, etc. [56].

Some government initiatives include the Agro-Industrial Pole Project in the Bélier region (2PAI-BELIER). Initiated in 2016, it has supported ICT-led agro-industrial transformation in the central part of the country. In 2019, the Government agreed to pay a living income differential for every tonne 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 first among the ECOWAS countries [52].

❖ **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 & 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 sector. Among the policies recently adopted to accelerate developments 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 [57].

In, 2014, a national cybersecurity policy was enacted which presents food and agriculture as one of the vital infrastructure and areas needing investment for national economy transformation. A digital agriculture policy, strategic plan and action plan have also been designed to support e-agriculture development in the country. 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 is initiated to spearhead the changes [52].

❖ **NIGERIA policies and strategies for digital agriculture**

The current status of digital agriculture in Nigeria is the result of a stepwise progress. Since 1992, the Nigerian government have enacted the National Broadcasting Commission (NBC) Decree 38 and the Nigerian Communications Commission (NCC) Decree 75, which the has brought a steady transformation in the ICT environment. As result, there have been an increasing interest in the broadcasting and telecom markets. In 2012, Nigeria's Federal Ministry of Communications (FMC) created the country's ICT strategy and developed 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. To date, Nigeria has become the largest mobile market in sub-Saharan Africa, powered by robust mobile broadband infrastructure and connectivity, that constitute a significant potential to improve the agri-food systems and employment.

The National Information Technology Development Agency (NITDA) is mandated to coordinate general IT policies and development in Nigeria [49]. In the agriculture sector, from 2011–2015, the Nigerian Government implemented the Agricultural Transformation Agenda (ATA), which has introduced business-like processes. Following the ATA, the Government launched the Agriculture Promotion Policy (2016–2020) in 2015 which anchored on multisectoral approach including digital innovations to support agricultural research and farming activities. The country has recently developed the Nigeria Digital Agriculture Strategy as a ten-year (2020–2030) plan that provides purpose and direction for adopting digital technologies in agriculture [49], which is set to transform the agri-food sector.

To enhance local trade and exports, the Government has introduced some policies and programs. These include the Nigeria–Africa Trade and Investment Promotion Programme, Presidential Economic Diversification Initiative, Zero Reject Initiative and Economic and Export Promotion Incentives. On other hand, the Economic Recovery and Growth Plan 2017-2020 (ERGP) has supported and encouraged digital entrepreneurship in agriculture. 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 for the diversification of business opportunities in agriculture [52,58].

3.3. IPRs and Digital Agriculture

IPRs are exclusive rights given to persons over the creations for a certain period (www.wto.org/index.htm). Applied to Digital agriculture, IPRs protect innovators using information and communication technology (ICT) to deliver timely information and services for the development of the agrifood sector. Regarding IPRs, 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 [59]. In addition, these countries are also member states of WIPO, which operates an online platform, accessible for innovators from the participating countries, to easily access IPR-related services [60].

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 industrial property as well as in the provisions of international conventions (www.oapi.int/index.php/fr/services).

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. On the other hand, Agri-digital innovations from public institutions such as national Universities are primarily protected by the IPRs [61] 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. 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 country member of the OAPI, the country also hosts a National Liaison Structure (NLS) of OAPI [62]. 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 /02/ 2005, in charge of administering the Intellectual Property system [63]. It also represents the African Intellectual Property Organization (OAPI) and the World Intellectual Property Organization (WIPO).

❖ **GHANA**

The country is a signatory of the Lusaka Agreement [64] on establishing the African Regional Intellectual Property Organization (ARIPO), which promotes IPRs among its member states. The Ghana Copyrights Office [65] 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 [66] governing intellectual property law. In January 2020, the WIPO Nigeria Office (WNO) was established in Abuja to promote awareness raising, training and capacity building in intellectual property (IP) and across WIPO's global services in Nigeria.

From 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 (Afolayan, 2022). 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, in 2019, Africa accounted for only 0.5 per cent of the world's patent applications, compared to 66.8 per cent for Asia, 19 per cent for North America and 10.9 per cent for Europe (UN & OSAA, 2022). Hence, these countries must not only quickly work to connect the digital sector and agriculture but also to provide an environment protective of the 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 agrifood system creating new opportunities hitherto untapped in all sectors from production to commercialization of value-added products [67]. 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 big 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. It is therefore important 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 an 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. [68], the most common barriers to full digital extension technology are unawareness, inaccessible mobile network, inaccessible electricity, inaccessible devices, slow access, unfamiliar language, insensitive to digital

illiteracy, insensitive to user's knowledge, insensitive to priorities, insensitive to socioeconomic constraints, irrelevant to farm. Factors such as high illiteracy and unawareness of digital technologies among small-scale farmers in the study countries still hamper the full development and adoption of digital agriculture. 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 key enabling factors, education and literacy, mainly digital literacy among the youths who are critical agents of the digital agriculture transformation.

The development of e-policies and e-strategies on e-content, e-trust, e-security, and e-value addition can champion sustainable e-agriculture [67]. 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 [52]. 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 that, 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. These can be done 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 Properties Rights protecting the developers of the agri-digital technologies/innovations (Figure 4).

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 experience from the industry and 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.
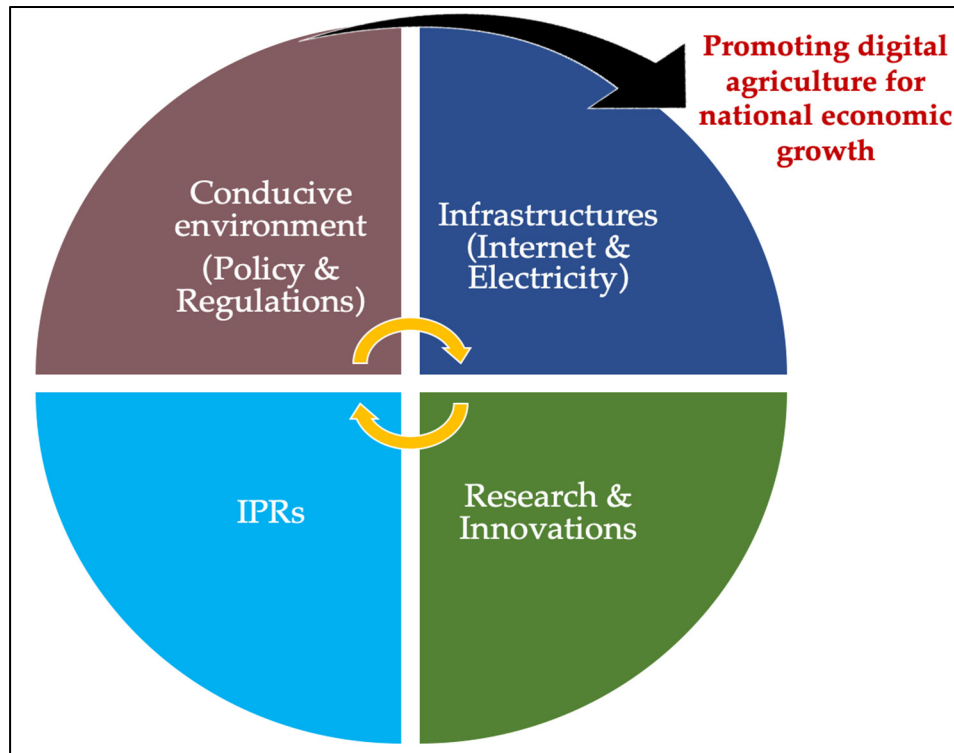
Figure 4. Electricity access rate[46] in the five AGriDI target countries by 2020.

5. Conclusions and perspectives

This study examined innovations, policies and strategies for the digitalization of agriculture in five West African countries: Benin, Ghana, Burkina Faso, Nigeria, and Côte d'Ivoire. Overall, these countries are making efforts to ensure the development of an enabling environment for digital agriculture. However, there is still a need for continuous commitment to deploy infrastructures and to strengthen the governance of the sector. In the five target countries, there are increasing agri-digital initiatives supported either by the public or private sector or result from a public-private partnership which includes projects or programs and solutions proposed by start-ups. All countries 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. On the other hand, regional harmonization is also required to allow countries to streamline the establishment of national e-agriculture strategy plans by encouraging integration and experience sharing per various regional and international treaties.

References

1. Evans, O. *Digital Agriculture: Mobile Phones, Internet & Agricultural Development in Africa*. Published in: Actual Problems of Economics, Vol. 7-8, No. 205-206, 2018,   pp. 76-90.

2. Ozdogan, B.; Gacar, A.; Aktas, H.. Digital agriculture practices in the context of agriculture 4.0. *Journal of Economics Finance and Accounting* **2017**, 4(2), 186-193. https://doi.org/10.17261/Pressacademia.2017.448

3. Xie, L.; Luo, B.;Zhong, W.. How are smallholder farmers involved in digital agriculture in developing countries: a case study from China. *Land* **2021**, 10(3), 245. https://doi.org/10.3390/land10030245

4. Ravis, T.; Notkin, B. Urban bites and agrarian bytes: Digital agriculture and extended urbanization. *Berkeley Planning Journal* **2020**, 31(1). https://doi.org/10.5070/BP331044067

5. FAO. Realizing the Potential of Digitalization to Improve the Agrifood System: Proposing a New International Digital Council for Food and Agriculture. A Concept Note. Available online : http://www.fao.org/3/ca7485en/ca7485en.pdf (accessed on 08 October 2022)

6. Willy, D.K; Diallo, Y.; Affognon, H.; Nang, F.; Waithaka, M.; Wossen, T. COVID-19 Pandemic in Africa: Impacts on Agriculture and Emerging Policy Responses for Adaptation and Resilience Building. TAAT Policy Compact Working Paper COVID19 Pandemic in Africa : NO. WP01/2020.

7. Fernando, A. J. . How Africa is promoting agricultural innovations and technologies amidst the COVID-19 pandemic. *Molecular Plant* **2020**, 13(10), 1345-1346. https://doi.org/10.1016/j.molp.2020.08.003

8. AGRA (2021). Role of digital agricultural tools during pandemic. Avalaibe online: https://agra.org/news/role-of-digital-agricultural-tools-during-pandemic/ (accessed on 06 Janaury 2023)

9. CTA. *The Digitalisation of African Agriculture Report*. Avalaible online: https://cgspace.cgiar.org/bitstream/handle/10568/103198/Executive%20Summary%20V4.5%20ONLINE.pdf

10. FAO and ITU. 2022. Status of digital agriculture in 47 sub-Saharan African countries. Rome. Avalaible online: https://doi.org/10.4060/cb7943en

11. Eweoya, I.; Okuboyejo, S. R.; Odetunmibi, O. A.; Odusote, B. O An empirical investigation of acceptance, adoption and the use of E-agriculture in Nigeria. *Heliyon* **2021**, *7*(7), e07588. https://doi.org/10.1016/j.heliyon.2021.e07588

12. Tokpon, A. Bénin : La digitalisation de l'agriculture s'implémente sous ACMA 2. Avalaible online: https://www.agratime.com/benin-la-digitalisation-de-lagriculture-simplemente-sous-acma-2/.   (accessed on 31 october 2022)

13. World Bank. Benin: World Bank Provides $100 Million to Promote Digital Solutions in Rural Communities. Avalaible on: https://www.worldbank.org/en/news/press-release/2019/07/01/benin-world-bank-provides-100-million-to-promote-digital-solutions-in-rural-communities (accessed on 28 october 2022)

14. Hounongbé C.. E-agriculture au Bénin: acteur-agricole.bj et agrizonecna.com au service du monde rural. Avalaible online: https://lanation.bj/e-agriculture-au-benin-acteur-agricole-bj-et-agrizonecna-com-au-service-du-monde-rural/ (accessed on 04 october 2022)

15. Agridigitale. L'agriculture de précision débarque au Bénin. Avalaible https://agridigitale.net/art-l_agriculture_de_prcision_dbarque_au_bnin_.html# (accessed on 04 october 2022)

16. JINUNKUN SARL. Feeding Africa with its own food. Avalaible online: https://jinukun.bj/ (accessed on 04 october 2022)

17. M-Agri. Avalaible: https://www.orange.ci/fr/m-agri.html. (accessed on 04 october 2022).

18. Abubakar Y. GHANA E-Agriculture Programme Ministry of Food and Agriculture, Republic of Ghana. Avalaible online: https://www.fao.org/e-agriculture/news/ghana-e-agriculture-programme-ministry-food-and-agriculture-republic-ghana. (accessed   on 04 october 2022).

19. BUY FROM WOMEN. Avalaible online: https://blaatto.com/en/homepage/ (accessed on 28 october 2022)

20. Palmafrique. Lôr Bouôr : Union entre l'agriculture et les TIC. Avalaible online: http://www.palmafrique.com/lor-bouor-union-entre-lagriculture-et-les-tic/ (accessed on 02 November 2022)

21. Lôr Bouôr. Présentation. Avalaible online: http://lorbouor.org/presentation/ (accessed on 02 November 2022)

22. CTA Blog. TechShelta: Greenhouse farming solutions powered by digital technology. Avalaible online: https://www.cta.int/en/blog/all/article/techshelta-greenhouse-farming-solutions-powered-by-digital-technology-sid0e4b43878-825a-49f2-b960-7a1c7a7e27c2. (accessed on 28 october 2022)

23. Agro Innova. Our Services. Avalaible online: https://agroinnovagh.com/index (accessed on 28 october 2022)

24. TradeNet.biz. Avalaible online: http://www.tradenet.biz (accessed on 28 octobre 2022)

25. NEAWP. Avalaible online: http://www.eagriculture.gov.ng/eagricportal/ (accessed on 04 october 2022)

26. ANADER. Digitalisation du conseil agricole : une assistance de proximite de l'ANADER a travers les TICs Avalaible online online: http://www.anader.ci/digitalisation_du_conseil_agricole_une_assistance_de_proximite_de_l_anader_a_travers_les_tics.html (accessed on 04 october 2022)

27. Cio Mag. Côte d'Ivoire : la startup Wi-Agri chausse les bottes des producteurs d'anacarde. Avalaible: https://cio-mag.com/cote-divoire-la-startup-wi-agri-chausse-les-bottes-des-producteurs-danacarde/. (accessed on 04 october 2022).

28. Adjimehossou F.. TICs et agriculture au Bénin : en milieu rural, des start-ups montrent le chemin. Available online : https://www.fraternitebj.info/societe/article/tics-et-agriculture-au-benin-en-milieu-rural-des-start-ups-montrent-le-chemin(accessed on 04 october 2022)

29. Alexandre Chloé, Bationo Modeste Florentin. Une transformation des services de conseil agricole grâce au numérique ?. *Grain de Sel* (77) : 2019, pp. 8-9.

30. Burkina NTIC. Semaine National de l'Internet 2018 : Des drones pour des agriculteurs. Avalaible online: https://burkina-ntic.net/spip.php?article2329. (accessed on 04 october 2022)

31. Esoko. Connecting You to The Last Mile. Avalaible online: https://esoko.com/who-we-are/ (accessed on 28 october 2022)

32. Federal Ministry of Information and Culture: FG launches national e-agriculture web portal. Avalaible online :https://fmic.gov.ng/fg-launches-national-e-agriculture-web-portal/ (accessed on 06 october 2022)

33. Yam-Pukri & CTA. *TIC et Agriculture au Burkina Faso: Étude sur les pratiques et les usages*. 2020, 193p

34. Livestock247. Avalaible online: https://livestock247.com/ (accessed on 28 october 2022)

35. World Bank. Benin: World Bank Provides $100 Million to Promote Digital Solutions in Rural Communities. Avalaible online: https://www.worldbank.org/en/news/press-release/2019/07/01/benin-world-bank-provides-100-million-to-promote-digital-solutions-in-rural-communities. (accessed on 28 october 2022)

36. ITC4Agr-Bénin. Applications numériques à l'Agriculture et à l'Environnement : des nombres a la terre. Avalaible on : http://www.itc4agr-benin.org/index.php (accessed on 28 october 2022)

37. Barry A. G. . Accès au financement agricole par le digital : Farafina Agri-funding, une solution de financement participatif. Avalaible online: https://burkina24.com/2022/07/30/acces-au-financement-agricole-par-le-digital-farafina-agri-funding-une-solution-de-financement-participatif/. (accessed on 04 october 2022)

38. Spore. Ghana: Digital vaccine delivery service. Avalaible on https://spore.cta.int/en/dossiers/article/ghana-digital-vaccine-delivery-service-sid0f8cd8489-ff6d-4c69-aebd-d779263b5715. (accessed on 04 october 2022)

39. TROTRO Tractor Limited. Tractor at Your Service in Ghana Like TROTRO. Avalaible on: https://www.trotrotractor.com/ (accessed on 28 october 2022)

40. Uduji, J. I.; Okolo-Obasi, E. N.;Asongu, S. A. The impact of e-wallet on informal farm entrepreneurship development in rural Nigeria. *The Electronic Journal of Information Systems in Developing Countries* **2019**, *85*(e12066), 1–21. https://doi.org/https://doi.org/10.1002/isd2.12066

41. Afrimash. Avalaible online: https://www.afrimash.com/ (accessed on 28 october 2022)

42. OECD. *The digital transformation of the agriculture and food system*. February available online : https://doi.org/10.1787/18156797

43. GSMA. The mobilie connectivity index. Avalaible online: https://www.mobileconnectivityindex.com/ (accessed on 08 October 2022)

44. Tossou, H. S.; Okou, F. A.y.; Kpanou, S B. A Systematic Review of Policy Enforcement as a Catalyst for Digitalizing Agriculture in West and East Africa. *Journal of African Development* **2021**, *21*(1), 68. https://doi.org/10.5325/jafrideve.21.1.0068

45. The World World Developement World Bank Indicators (WDI): Individulas using the internet (% of Population). Avalaible online:https://databank.worldbank.org/reports.aspx?source=2&series=IT.NET.USER.ZS&country=# (accessed on 08 October 2022)

46. IEA, IRENA, UNSD, the World Bank, WHO . The Evergy Progress Report. Avalaible online https://trackingsdg7.esmap.org/ (accessed on 08 October 2022)

47. FAO. *National e-agriculture strategy*. 4p avalaible on: https://www.fao.org/3/I8133EN/i8133en.pdf

48. MAEP, MENC, ITU, & FAO. *Stratégie nationale pour l'e-Agriculture au Bénin 2020-2024*. 2019, 56p

49. NITDA. *Nigeria Digital Agriculture Strategy (2020-2030)*. 2020, 47p

50. MAEP. *Plan Stratégique de Développement du Secteur Agricole (PSDSA) 2025 et Plan National d'Investissements Agricoles et de Sécurité Alimentaire et Nutritionnelle*.

51. Presidency of the Republic of Benin. *Government Action Programme 2021-2026*.

52. FAO, & ITU. *Status of digital agriculture in 47 sub-saharan african countries*. 2021, 351p

53. MDENP. *Stratégie Nationale de Développment de l' Economie Numérique 2018-2027*. 2018, 69p. Avalaible online : https://www.fonction-publique.gov.bf/fileadmin/user_upload/storage/21_juillet_2021-05-SNPG_Version_finale.pdf

54. World Bank, AAA, WASCAL, IFAD, AFD, UE, CIAT, CGIAR, World Agroforestry. *Climate-Smart Agriculture Investment Plan: Burkina-FASO*. Avaialable online : www.worldbank.org

55. Traore, S. A.;Mabaya, E.;Afun-Ogidan, O. D.; Ajilore, B.; Girvetz, E.; Jarvis, A.; Kropff, W. *Digital Agriculture Profile : Cô te D'Ivoire*. 2021, 15p. Avaliable online: https://www.fao.org/3/cb2505en/cb2505en.pdf

56. MADR. *Programme National d ' Investissement Agricole de Deuxième Génération (2018-2025)*. 2017, 12p Available online : https://www.gafspfund.org/sites/default/files/inline-files/7a.%20Ivory%20Coast_Investment%20Plan.pdf (accessed on 08 October 2022)

57. Republic of Ghana. *The Ghana ICT for Accelerated Development (ICT4AD) Policy*. 86p, Avalaible onine : https://nita.gov.gh/theevooc/2017/12/Ghana-ICT4AD-Policy.pdf

58. FEDERAL GOVERNMENT OF NIGERIA. Nigeria ICT Roadmap 2017-2020. 25p Available online: https://nesgroup.org/download_policy_drafts/Nigeria_ICT_Roadmap_2017-2020_1661853858.pdf

59. UN, OSAA. The Role of Intellectual Property Rights in Promoting Africa's Development Overview of IPR in Africa. Avaliable on : https://www.un.org/osaa (accessed on 08 October 2022).

60. WIPO. Intellectual Property Services. Avaliable online: https://www.wipo.int/services/en/ (accessed on 08 October 2022)

61. University Ghana. Intellectual Property Policy. 10p Available on: https://orid.ug.edu.gh/sites/orid.ug.edu.gh/files/UG%20Intellectual%20Property%20Policy.pdf

62. OAPI. Structure Nationale de liaison. Avalaible online : http://www.oapi.int/index.php/fr/oapi/organisation/structures-nationales-de-liaison (accessed on 10 October , 2022)

63. OIPI. Office Ivoirien de la Propriété intellectuelle. Avaialable online: https://www.oipi.ci/

64. ARIPO. *Lusaka Agreement* , 2016 Edition. 18p

65. Ghana Copiright Office. Avalaible online : https://www.copyright.gov.gh/ (accessed on 08 october 2022)

66. Resolution Law Firm. Overview of the Intellectual Property Law in Nigeria. Avaliable online https://www.resolutionlawng.com/overview-of-the-intellectual-property-law-in-nigeria/ (accessed on 08 october 2022)

67. Maumbe, B. M.. The development of e-Agriculture in Sub-Saharan Africa: Key Considerations, Challenges, and Policy Implications. In *E-agriculture and E-government for Global Policy Development: Implications and Future Directions* 2010, pp. 73-93). IGI Global.

68. Coggins, S.; McCampbell, M.; Sharma, A.; Sharma, R.; Haefele, S. M.; Karki, E.; Hetherington, J; Smith, J; Brown, B. How have smallholder farmers used digital extension tools? Developer and user voices from Sub-Saharan Africa, South Asia and Southeast Asia. *Global food security* **2022**, *32*, 100577.