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Policy Innovation for Transforming Africa's Food System with Digital Technologies

A Malabo Montpellier Panel Report 2019

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Foreword

Commendable progress has been made across many parts of Africa over the past years to increase agricultural productivity, reduce hunger, malnutrition and poverty, create new employment opportunities for young people and improve the livelihoods of rural communities. Yet, demographic change, urbanization, shifting diets and climatic changes mean that pressure is growing on food systems to make more food and more varied and nutritious food available and accessible. Sustaining past progress and responding to emerging pressures requires innovative means of resolving faster and at scale the host of institutional, infrastructural and technological obstacles to future gains in productivity and competitiveness in Africa's food value chains. New digital technologies and services are already having a considerable impact on how food is being produced, processed, marketed, traded and consumed across the continent. How African countries position themselves to harness and deploy digital technologies will determine the future competitiveness of African agriculture and its contribution to African economies.

The current report—***Byte by Byte: Policy Innovation for Transforming Africa's Food System with Digital Technologies***—summarizes the key findings of a systematic analysis of what seven African countries at the forefront of progress on digitalization of the agriculture sector have done right. It analyzes which institutional and policy innovations were implemented and what actions were taken by the private sector and agtech start-ups to increase the development and use of digital tools and services in the agriculture value chain. Several of these can be brought to scale across the continent to help governments meet the targets and goals under the African Union Agenda 2063, the Malabo Declaration on agricultural transformation and the Sustainable Development Goals (SDGs). The objective of this report is to identify interventions that work and benefit famers and other actors in the value chain and recommend options for policy and program innovation that allow countries to develop a "digitalization ecosystem" in which digital technologies and services can be developed and used to foster growth and competitiveness in Africa's agriculture value chains. Efforts need to be supported by governments and the private sector, and crucially, any agriculture digitalization strategy needs to be designed to fit local environments and meet the needs of all value chain actors, while creating new opportunities for Africa's youth and women.

The Malabo Montpellier Panel convenes 17 leading experts in agriculture, ecology, nutrition and food security to guide policy choices by African governments to accelerate progress toward food security and improved nutrition in Africa. The Panel identifies areas of progress and positive change across the continent and assesses what successful countries have done differently. It then identifies the most important institutional innovations and policy and program interventions that can be replicated and scaled up by other countries. The related Malabo Montpellier Forum provides a platform to promote policy innovation by using the evidence produced by the Panel to facilitate dialogue and exchange among high-level decision-makers on African agriculture, nutrition and food security.

Ousmane Badiane
Co-Chair

Joachim von Braun
Co-Chair

THE MALABO MONTPELLIER PANEL

The core mission of the Malabo Montpellier Panel, a group of leading African and international experts from the fields of agriculture, ecology, food security, nutrition, public policy and global development, is to support evidence-based dialogue among policy makers at the highest level. The Panel's reports seek to inform and guide policy choices to accelerate progress toward the ambitious goals of the African Union Commission's Agenda 2063, the Malabo Declaration and the global development agenda. The Panel works with African governments and civil society organizations to provide support and evidence-based research that facilitate the identification and implementation of policies that enhance agriculture, food security and nutrition.

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1. Introduction

Across many parts of Africa commendable progress has been made over the past two decades in addressing some of the key challenges to sustained agricultural transformation, economic prosperity and improved livelihoods. However, the combined pressures of demographic changes, urbanization, shifting diets, climate change and protracted crises require a new set of innovative solutions. The growing use of digital technologies, tools and services is widely visible, including in the agriculture sector, and will play a key role for African countries in meeting their targets on poverty reduction, food security and nutrition.

Africa's digital transformation is already underway, and the continent now has the opportunity to leverage the potential benefits of digitalization and new technologies for agriculture, as well as to avoid the pitfalls that digitalization can pose. A sound digitalization environment that embraces smallholder farmers and other actors along the agriculture value chain will ensure that Africa's rural areas are not left behind.

How African countries position themselves to harness and deploy digital technologies will determine the future competitiveness and sustainability of African agriculture and its contribution to African economies. In fact, the so-called Fourth Industrial Revolution can be an opportunity for African countries to leapfrog and lead the way in the application of digital technologies along the agriculture value chain. While some technologies may be out of reach for most value chain actors for now, this is an opportune moment to devise appropriate strategies to equip the next generation of farmers with the right set of digital skills to be able to harness those digital solutions and services still on the horizon.

At its simplest, information and communications technology (ICT) enables farmers to digitize farm operations. Farm management applications can give farmers an overview of their farm processes at the touch of a button, and expedite decision-making as a result. At the other end of the scale, more complex technologies and platforms are redefining how stakeholders along the value chain and across public, private and civil society sectors work together to transform the whole sector. For example, the use of the internet of things (IoT) can automate the generation of large amounts of data, thereby enabling easier and faster analysis of matters such as land degradation, drought, and infrastructure utilization. Given that Africa has been using innovative technologies to leapfrog economic development in some sectors such as banking, for instance, there is now an opportunity for African governments to champion the Fourth Industrial Revolution in the agriculture sector.

Africa's rural areas, and smallholder farmers in particular, could greatly benefit from access to new technologies and reliable data that would help them make more informed decisions and get more value from their produce. A wide array of challenges facing smallholder farmers can be addressed by deploying digital solutions. Emerging digital technologies such as blockchain, big data, robotics, and the IoT, as well as more low-tech, frugal innovations, are disrupting industries in many countries and changing the way people communicate, access information, and sell and buy products and services. In essence, digitalization is an opportunity to generate wealth and improve livelihoods globally.

Key benefits of digitalization include greater access to information and services including finance and links to markets.

Key benefits of digitalization include greater access to information and services including finance and links to markets. Digitalization can lead to a sustainable increase in productivity, and importantly, to better informed, data-driven policies. It can help to overcome the geographic, social and economic isolation of rural farming communities and connect them better to other segments of the value chain, while the ability to broadcast information fast and cost-effectively can bring successful technologies to scale more quickly.

Digital innovation is reshaping industries and economies globally by disrupting existing business and operating models. But it is also having a profound impact on societies as a whole, presenting a series of opportunities and challenges for consumers, entrepreneurs and policymakers. The falling cost of advanced technologies and mobile internet is a defining characteristic of the digital revolution and has been playing a major role in accelerating innovation. For example, the price for mobile internet in Africa has dropped by 30 percent since 2015.[1]

However, while Africa has seen a rising level of mobile technology adoption in recent years, it continues to lag in technology development and content creation. The growing IT skills gap and lack of digital literacy, as well as funding for agtech start-ups will, if not addressed, limit the region's efforts to join or even lead the Fourth Industrial Revolution. With a rapidly increasing young population, African governments need to prioritize their education systems to ensure that they are developing the skills that match the growing trend toward technology adoption in the agriculture sector.

Although the application of new technologies in African agriculture is rather new, important lessons can be learned from successful interventions in several African countries that could be replicated and brought to scale across the continent. This report begins with an overview of the state of digitalization in African agriculture and the opportunities for the use of digital technologies at each segment of the agriculture value chain, from preharvest to consumption. Concrete examples of technologies, apps and projects are part of this discussion. The next section reviews the limitations and the potential risks of digitalization. The report then describes what policies and regulations are needed to create an enabling digitalization environment that benefits Africa's rural communities and smallholder farmers. This is followed by an analysis of the experiences of seven African countries that have been at the forefront of the application of digital innovations in the agriculture sector through institutional innovation and innovative policymaking—Côte d'Ivoire, Ghana, Kenya, Morocco, Nigeria, Rwanda and Senegal. The report closes by drawing some key lessons and offering nine recommendations for action by African governments and the private sector.

Definitions

Artificial intelligence (AI) – AI is the ability of machines and systems to acquire and apply knowledge and to carry out intelligent behavior. These AI or cognitive-based technologies help computers interact, reason, and learn (machine learning) to enable them to perform a broad variety of cognitive tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, translation between languages, and ability to move and manipulate objects. Intelligent systems use a combination of big data analytics, cloud computing, machine-to-machine communication and the IoT to operate and learn.[2,3]

Big data – Big data is defined as open, harmonized, interoperable and integrated datasets from multiple domains intended to accelerate (agricultural) research and data use in service of a development goal. Big data is built on other systems, such as those that use the cloud.[4] ICTs, including the internet as well as connected sensors capturing the physical world, are increasingly generating large volumes of digital data. These large streams of data, and the capacity to combine them, are referred to as big data.[5] The datasets are so large or complex that traditional data processing application software is inadequate to handle them.

Blockchain – Blockchain technology provides a digital, decentralized, and distributed ledger that allows various actors to input, receive and retrieve the same information using a technological backbone that makes rule-breaking, hacking, and dishonesty exceedingly difficult to almost impossible.[6] Blockchain is an effective tool for verifying proof of existence, full records, and the ownership or origin of exchanged information. By integrating smart contracts (computer programs that run autonomously as soon as certain criteria are met), the technology promises to reduce procedural delays and costs and systematize controls. The aim is to bring this traceability all the way from the farm to the consumer.[7]

Digital divide – Digital divide refers to the inequality in the access to, use of, or impact of ICTs. Although digital technologies can boost growth, create new opportunities and improve service delivery, the benefits often do not reach the most remote and marginalized communities. Several factors underlie the digital divide, including connectivity, affordability, electricity, education, knowledge, skills, gender, age and location.[8]

Digital infrastructure, platforms and services – A group of technologies that are used as a base upon which other applications, processes or technologies are developed. Platforms can also be a business framework that allows multiple business models to be built and supported.[9] Digital platforms collate information and promote broader access to, and more effective use of a range of information and services. Digital platforms are created and cultivated on top of digital infrastructure, which include the computing and network resources that allow multiple stakeholders to design their service and content needs. Digital infrastructure includes the internet, data centers and open standards, as well as consumer devices such as smartphones and tablets.[10] Platforms allow the development of digital services where the services delivery to the customer uses only an online channel.[11]

Digitalization for agriculture – In contrast to digitization, which refers to creating a digital version of information and data[12], digitalization for agriculture is the use of digital technologies, innovations, and data to transform business models and practices across the agriculture value chain, including production, postharvest handling, market access, finance and supply chain management.[13]

Frugal innovations – Frugal innovations are defined as innovations that reduce the complexity and cost of machines and tools and their production, and making them more suitable to local contexts.[14,15]

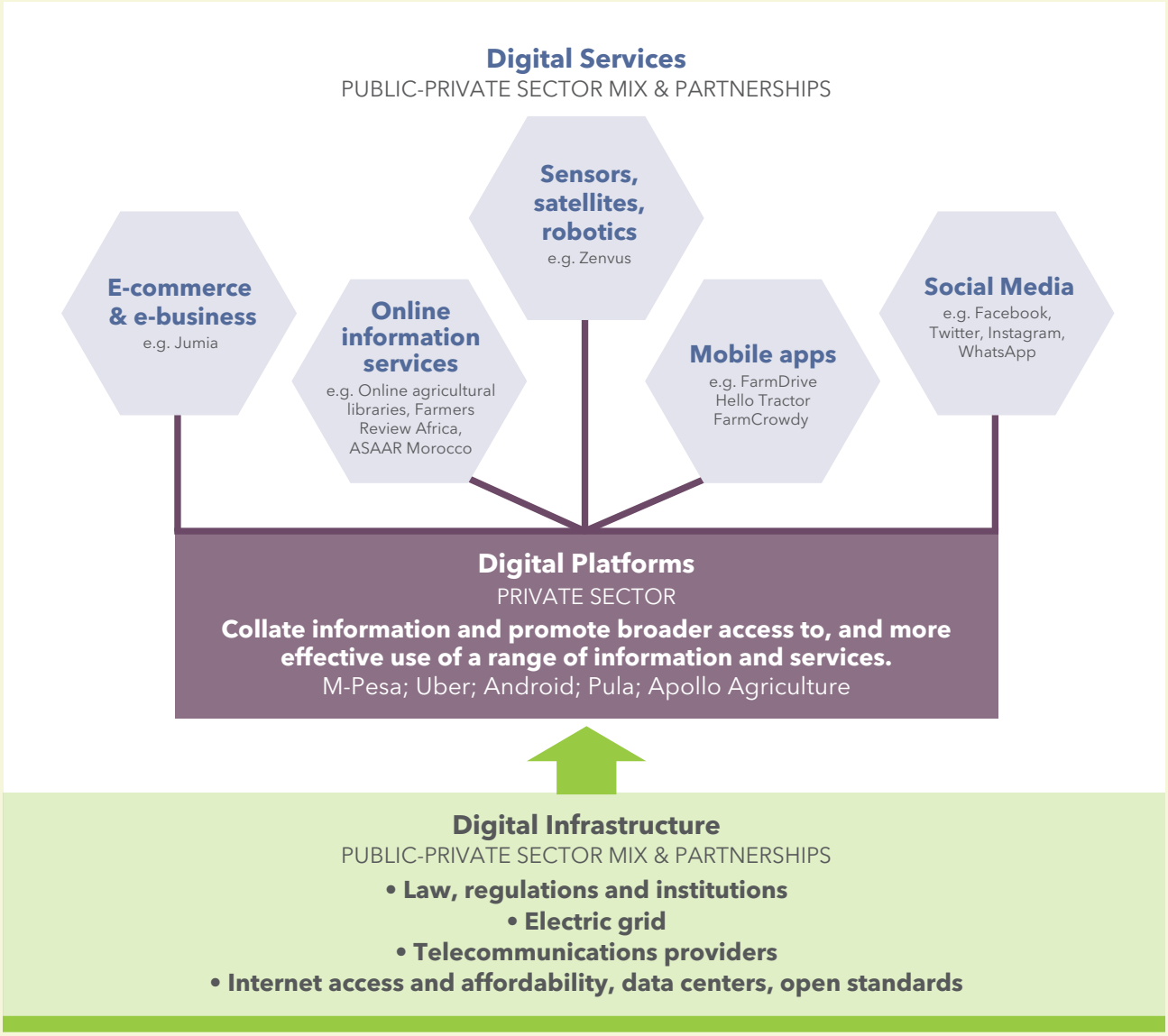
Internet of things (IoT) – The IoT is defined as the interconnection via the internet of computing devices embedded in everyday objects, enabling them to send and receive data, for example, in soil, farm tools and waterways. IoT is made up of various data gatherers (e.g., sensors) coupled with connectivity, which allows them to link to each other. In the most fundamental sense, the IoT allows one to capture data from a place without being there in person.[16]

Definitions *continued*

Precision farming – Precision farming involves new production and management methods that make intensive use of data about a specific location and crop. Sensor technologies and application methods are used to optimize agriculture production processes and growth conditions. Using digital data can increase resource and cost efficiency while reducing the environmental impact of agriculture.[17]

Robotics – Robots operate with some autonomy, performing projected tasks based on current state and sensing without human intervention. The International Federation of Robotics (IFR) differentiates between two types of robots, according to their use and working environment. An industrial robot is an automatically controlled, reprogrammable and multipurpose machine with a mechanical structure. A service robot performs useful tasks for humans or equipment, excluding industrial automation applications.[18] The opportunities for robotics include the development of field robots that can assist workers by conducting agricultural operations such as crop and animal sensing, weeding and drilling and the integration of autonomous systems technologies into existing farm operational equipment such as tractors.[19]

FIGURE 1 Typology of digital platforms



Source: Adapted from Koskinen et al. (2018)[20] Fig. 3.

2. Action Agenda

Africa now has the opportunity to leapfrog and leverage the potential benefits of digital innovation in the food system, while using targeted regulation to avoid the risks that digitalization can pose. Key lessons and recommendations can be drawn from several African countries at the forefront of digitalization in the agriculture sector. By adapting these lessons to countries' specific contexts and bringing them to scale across the continent, African governments can meet their national and international commitments on agricultural growth, economic transformation and poverty reduction. The Malabo Montpellier Panel recommends that governments establish a sound enabling digitalization environment, coupled with fiscal incentives and public investments to catalyze continued private sector innovation and engagement. Research and development (R&D) combined with digital literacy training and the creation of innovation hubs can furthermore create much needed opportunities for young people in the development of new digital agriculture technologies and solutions.

Several key factors distinguish the countries that have made the most progress in advancing digitalization of the agriculture value chain:

GOVERNMENT ACTIONS

1 *Placing digitalization at the core of national agricultural growth and transformation strategies and policies*

Digitalization of the agriculture sector needs to be placed at the core of national agricultural growth and transformation agendas in order to harness its cross-cutting innovative strength. By developing national digital agriculture strategies along with required public investments, governments can set out solid long-term visions for the design, development and use of new technologies along the agriculture value chain.

2 *Designing smart regulation for digital innovation*

Creation of a transparent regulatory environment that promotes the development and confident use of digital technologies and services and limits the risks is essential. Smart regulation should facilitate and spur entrepreneurial initiatives and competition, as well as access to technologies and services, including in rural areas, and their use across the agriculture value chain. It should also promote innovation and participation by and collaboration between multiple stakeholders, while ensuring a balance between the free flow of data and information, on the one hand, and privacy concerns, on the other.

3 *Strengthening education for digital innovation*

African universities should expand their curricula to include programming and algorithm design to become hubs for supporting digital innovations in the food system. This will also spur the development of an African agtech sector and stimulate entrepreneurship and innovation at smaller scale, including start-ups, and their financing. In addition, training and mentoring opportunities for e-agriculture entrepreneurs need to be increased by integrating relevant topics in university or vocational training curricula, coupled with business skills development.

4 *Providing skill development and digital literacy training for farmers and other actors in the food system*

Although many services still operate using simple SMS, digital literacy among farmers, extension agents and other value chain actors needs to be strengthened as technologically more advanced innovations are being developed. Farmers and other actors need to be equipped with the skills to access and use mobile technologies and digital services and to interpret the information received. Extension agents and advisory organizations play a key role in driving digitalization uptake in the agriculture value chain by disseminating information about new approaches and technologies to farmers, training them how to use and manage

technologies, and collecting data on farmers. To do this most effectively requires strengthening the capacity of extension agents to manage and analyze data and use it for the benefit of agricultural transformation in rural areas.

PRIVATE SECTOR ACTIONS

5 *Investing in research and development (R&D)*

There is a pressing need for R&D to develop digital tools and services that address the persistent challenges across the agriculture value chain, not just in farming but also around postharvest losses and processing. More investment in R&D is needed to develop both frugal and cutting-edge digital solutions that meet the needs of all value chain actors, in particular, youth and women.

JOINT ACTIONS

6 *Introducing fiscal incentives to spur digital innovation*

Fiscal incentives, including lower import duties initially, should be considered to facilitate market entry and the import of technologies until local markets are developed. Long-term finance needs to be made available, while (mobile) internet and hardware needs to be made affordable to rural communities. This can be achieved in part by setting fair competition standards for stimulating better services provision and lowering overall prices for consumers. Private finance, through private sector accelerator and innovation funds, can strengthen innovation-promoting links between governments, private entrepreneurs and farmers' groups.

7 *Investing in supportive and last-mile infrastructure*

To bridge the digital divide, rural communities need to be better connected to electricity (including renewable and off-grid), reliable telecommunications and internet connections, including fiber optic, for households, schools and workplaces. Governments and the private sector should consider emerging technologies that may allow them to leapfrog more traditional infrastructure approaches. The use of handsets and mobile internet also needs to be made more affordable and accessible for all agriculture value chain actors.

8 *Developing digital agriculture innovation hubs*

Digital innovation hubs create the innovation ecosystem that is needed to spur the digital transformation of the agriculture sector while providing opportunities and support for young people in the development of locally suitable technologies and digital solutions. More investment and support need to be provided to create more innovation hubs across the continent that are dedicated to developing solutions focused on food system transformation.

9 *Toward trusted digitalization: conducting impact evaluations and setting quality standards*

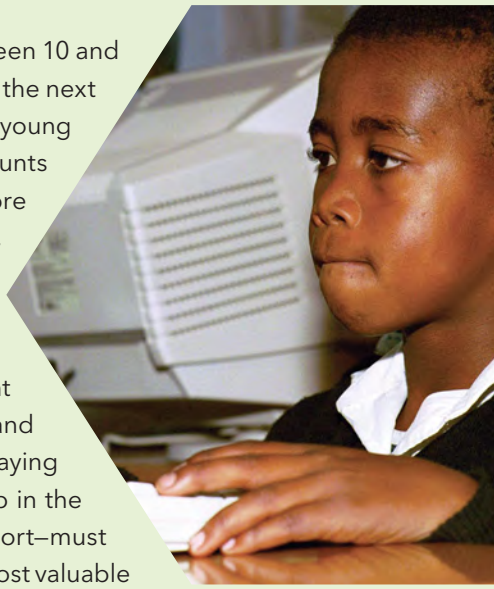
More investments need to be made to learn from the successes and failures of individual programs or technologies and to highlight gaps and opportunities for further skill development and capacity strengthening. To ensure digital applications and services meet quality standards, research centers can play an active role in the evaluation and impact assessment of specific technologies and e-services in rural areas. This would allow governments and the private sector to bring to scale those programs and interventions that are proven impactful and beneficial to rural communities. Quality control and standard setting of new technologies, digital tools and services requires the attention of business associations and governments.

3. Opportunities for Digitalization in African Agriculture

Digital technologies, services and tools can offer a plethora of opportunities to agriculture value chain actors to make more informed decisions, increase productivity and incomes, and achieve improved nutrition and health outcomes. If applied effectively, data from digitalization efforts can also be used to design better informed policies for agricultural transformation.[21] It is estimated that in developing countries, each additional 10 percent of internet penetration can lead to a 1.35 percent increase in per capita GDP growth.[22] A study in 81 countries revealed significant positive effects of an increase in ICT adoption and agricultural productivity.[23] In Kenya, findings show that farmers who participated in an ICT-based market information systems project had a higher use (or value) of seed and fertilizer per acre, as well as increased labor and land productivity.[24] Other evidence from Kenya shows that ICTs significantly facilitate the provision of agricultural extension services to farmers. An evaluation in 2015 found that extension officers using the Farmbook technology, a novel ICT tool for agricultural extension developed by Catholic Relief Services, reached significantly higher numbers of farmer groups compared to extension agents who relied on more traditional approaches.[25] This potential growth highlights the vast opportunities of digital technologies that can be harnessed for the benefit of smallholder farmers and the agriculture sector as a whole, with particular opportunities for Africa's youth.

Furthermore, in many parts of Africa, rural communities apply their own food production, processing and storage practices based on indigenous knowledge, passed on through generations. Farmers often also have specific knowledge on the nutritional value and other characteristics of indigenous crops, such as a crop's tolerance to drought or heat. Digital technologies can play an important role in facilitating the storage, access, retrieval and sharing of such knowledge for the benefit of value chain development and food systems transformation.[26,27] The digitalization of Africa's food system presents new opportunities for the use of digital and data-driven technologies at each segment of the agriculture value chain, which can guide and support decisions on production methods, value chain optimization and storage methods to avoid food waste and loss.

Youth empowerment



Agricultural digitalization is an opportunity for Africa to leverage its youth bulge. Between 10 and 12 million young people are expected to enter the African labor market each year over the next decade.[28] While some African countries have seen a growth in formal employment, most young people are likely to work in informal, often low-paid jobs. Currently, farming alone accounts for about 60 percent of total employment across the continent, and significantly more when jobs along the entire food value chain are taken into account. In Ethiopia, Malawi, Mozambique, Tanzania, Uganda and Zambia, for example, the food system is projected to add more jobs between 2010 and 2025 than the rest of the economy, yet young people show little or no interest in pursuing employment opportunities in the agriculture sector.[29] However, digital technologies are rapidly changing the agriculture employment landscape, creating jobs that require a new set of skills and that are more profitable and appealing to the youth. For young Africans to be able to compete for high-tech, better-paying jobs and to harness the increasing opportunities for innovation and entrepreneurship in the agriculture sector, digital skill and literacy training—as discussed in Section 5 of this report—must be at the heart of young people's education and training. Africa's young people are its most valuable asset. The entrepreneurial spirit of Africa's youth visible in many parts of the continent reflects how Africa is becoming innovative in finding locally relevant solutions to daily challenges in agriculture, health and education. Fostering a business-friendly environment and culture of entrepreneurship will be key to harnessing this spirit. A long-term, sustainable transformation of the agriculture sector through the use of digital technologies and services therefore requires improved access to quality education. Investing in education and practical and transferable skills training—such as programming, data science, and user interface design—is an opportunity to fortify Africa's greatest asset: its people. Governments and the private sector need to create the right ecosystem that will enable young people to succeed.

At planning level

Enable access to timely, reliable and accurate information

Land rights

Farmers base labor use and finance decisions on the potential return on investment. In this context, land rights—including the rights to use, control and transfer land—affect these decisions. Secure land tenure enables farmers to invest in long-term improvements to their farms and soils with the expectation that they will reap the benefits of those investments.[30] Accordingly, land property rights are a key factor for improving living conditions since they enhance the investment in agricultural production, food security, economic growth, and natural resource management, and help reduce socioeconomic gender inequalities.[31] Moreover, evidence shows that land security enhances sustainable land management practices.[32]

In many African countries, land rights are managed through complex, often opaque arrangements. Geospatial data related to landholdings are not easily available or cross-referenced against official data on landholdings in text documents. It is therefore difficult to prove ownership of land and use it as collateral for credit. Smartphones, cameras or drones, which can capture geospatial and topographical data—using, for example, Global Positioning Systems (GPS) and global navigation satellite systems—are therefore useful tools for land mapping and land tenure programs.[33] In Tanzania, drones are being used to support such a land tenure program. Moreover, saving this geospatial data along with land transaction histories, such as contracts and assets through blockchain technology, could make African land registries more robust.[34]

In 2016, the **Tanzanian Ministry of Lands** piloted the use of drones equipped with sensors as an option for acquiring aerial imagery to support a national land tenure program. Aside from confirming the viability of the drones as a practical alternative to manned aircraft and satellites as a source of aerial imagery, the study also determined near absolute accuracy to within 2 cm. Initially, the objective was to fly over an area of 24 km^2, but this was exceeded by surveying a total area of 147 km^2. The work in Tanzania has stimulated much interest both within Africa and internationally in the use of drones for land tenure systems.[35]

Weather forecasting

Most African farmers continue to rely on traditional knowledge about the weather and seasons as access to reliable weather information is rare, primarily due to outdated weather stations and a lack of historical or up-to-date meteorological data.[36] At the same time, farmers are already battling the adverse impacts of climate change. Access to reliable weather information and forecasts through modern weather station technology and improved weather forecasting, in combination with clear communication through mobile or online services, could allow farmers to make more informed decisions on when to sow, plough or harvest.

New weather technologies and prediction models make faster and more accurate forecasts available.[37] They are mainly accessible through text messaging (SMS), but also as interactive voice response (IVR) and interactive messaging services (Unstructured Supplementary Service Data, or USSD). An IVR service allows a farmer to call and communicate with a computer to obtain the needed information, while a USSD service enables interactive text

Access to reliable weather information and forecasts through modern weather station technology and improved weather forecasting, in combination with clear communication through mobile or online services, could allow farmers to make more informed decisions on when to sow, plough or harvest.

messaging between a computer and a farmer.[38] Nigeria successfully launched two earth observation satellites in 2011, which are used to monitor the weather and predict and manage flood areas.[39] Ignitia, a Swedish company, developed a tropical forecasting model for West Africa with an accuracy of 84 percent, providing daily weather forecasts to farmers via SMS in their local languages for just a few US$ cents per day. Farmers using the service in Côte d'Ivoire, Ghana, Mali, Niger, Nigeria and Senegal are better able to cope with and withstand weather variabilities using the localized rainfall predictions.[40] In Ethiopia, a pilot project provided local weather forecasts, including information on temperature and rainfall, to 1,500 sesame farmers via SMS in two local languages. Ninety-six percent of farmers rated the accuracy of rainfall forecasts as being (close to) very accurate. With this information, the farmers were able to better plan when to sow, weed, apply fertilizers and hire seasonal labor.[41] As a result, weather information may also help to achieve higher yields under rainfed agriculture or allow farmers to pursue an additional growing season.[42]

In 2015, the **CropMon** project started in Kenya, offering advisory services for small-scale farmers cultivating coffee, maize, grass, wheat and sugarcane. Using SMS, CropMon provides real-time information to famers on production conditions and rainfall and temperature forecasts, based on satellite measurements and local soil analysis. The exact location of each farm is registered in a database, allowing for specific and localized information. Currently, the project involves 150,000 farmers, with plans to develop a mobile app to make access even easier.[43,44]

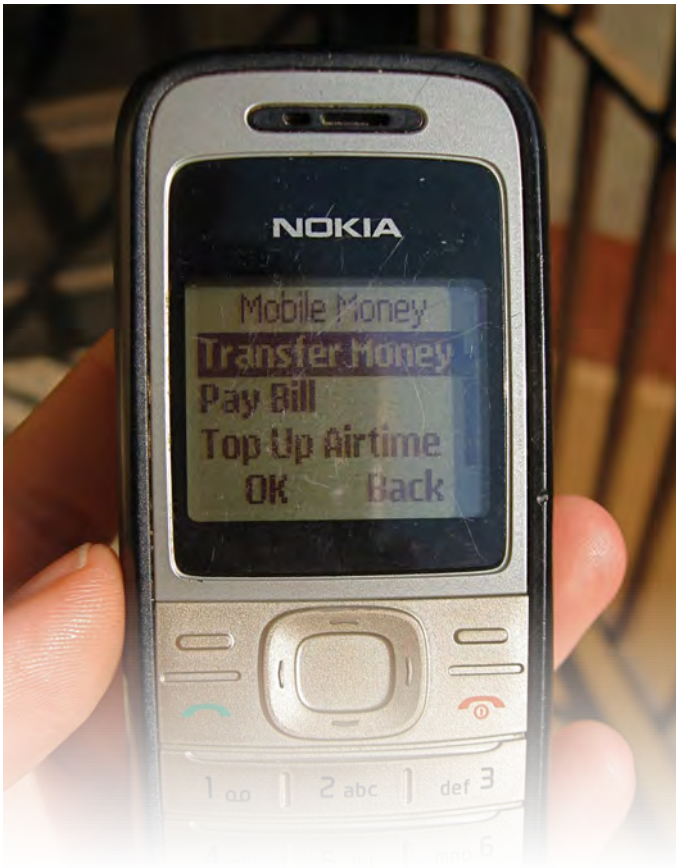
Access to and adoption of inputs

Enable access to finance and establish creditworthiness

Finance

Most smallholder farmers in Africa still lack access to formal financial institutions and miss out on access to basic banking services, loans and pensions. In the short-term, access to finance affects farmers' operational decisions, such as investing in seeds and other inputs, choice of crop, timing of harvest and sales. It also determines their longer-term decisions on the management and implementation of production methods.[45] In 2017, only one-third of adults in rural SSA owned a bank account and only five percent held a loan from a formal financial institution.[46] While access to formal finance remains low, new technologies can offer easier access to simple banking, saving and transfer functions.[47] In 2018, a study in Mozambique showed that access to a bank account increased the amount of savings in mobile money, as well as aggregate household savings. More importantly, higher savings enhanced the likelihood of fertilizer use, which increased by about 30 percent among famers.[48]

M-Pesa (M is for mobile, "pesa" is Swahili for "money") is a mobile money application founded by Vodafone for Safaricom in 2007 in Kenya. M-Pesa allows people from all around the country, even in the most remote areas, to transfer money directly, saving considerable amounts of time and money. In 2018, 22.5 million active users[49] worldwide were registered—about 70 percent of the adult population of Kenya. Since its founding, M-Pesa has expanded significantly into other services, including as a mechanism for increasing personal savings, and new clients, such as businesses.[50] A study from Kenya revealed that access to M-Pesa increased per capita expenditures and helped 194,000 households move out of poverty between 2008 and 2014. The changes were driven by differences in financial behavior, increased financial resilience and the ability to save.[51]



In Mali and Senegal, **myAgro** developed a mobile layaway platform allowing farmers to pay on layaway, whenever they have cash available, using their mobile phones. The myAgro system allows farmers to buy myAgro cards and layaway from US$1 to $50 to purchase seed and fertilizer for the planting season. When famers buy myAgro cards, the card codes and amounts are sent by text message to myAgro's database, and the individual farmers' accounts are credited by myAgro. myAgro then delivers purchased high-quality seed and fertilizer in bulk at planting time directly to farmers and provides training on best farming practices. Currently, up to 18,000 farmers in Mali and Senegal use mobile layaway via myAgro to save for seeds and fertilizer. Thanks to its ease of use, transparency and scalability for increasing investment in farms, myAgro has been effective in boosting yields and income. In fact, 80 percent of participating farmers used the myAgro planting method—microdosing fertilizer in small amounts per plant to maximize yields. Harvests of farmers using myAgro increased up to 100 percent, equivalent to US$350 in additional income.[52]

Creditworthiness

To finance small-sized farm operations and buy inputs or machinery, most smallholder farmers draw on the support of their relatives and friends or tap into their own savings and retained earnings.[53] While agriculture as a sector continues to be regarded as risky for banks to lend to, smallholder farmers in particular are often deemed too risky for loans and investments. This is partially due to low financial literacy, but primarily to the difficulty in determining farmers' creditworthiness and default rate on loans. Although there are some examples of linking smallholder farmers directly to microfinance institutions in rural areas, these have not reached scale. In this context, ICTs can be a powerful tool to help lower the risks associated with agricultural lending and establish trust between farmers and other value chain actors, including farmer organizations and financial institutions.

By recording farm performance data and financial transactions, including productivity, expenses and revenues, farmers can build comprehensive credit profiles. Lending institutions can combine this data with more sophisticated technology, such as machine learning and blockchain, to derive reliable lending decisions. For instance, FarmDrive in Kenya collects and aggregates data from multiple sources to build credit scores for farmers. Thus, financiers can benefit from a broader spectrum of clients who are fundable and profit from the accuracy of online data collection, reducing errors and increasing efficiency.[54]

FarmDrive uses mobile phones, alternative data and machine learning to close the critical data gap that prevents financial institutions from lending to creditworthy smallholder farmers. Based on a farm's data (productivity levels and accounting), as well as satellite, agronomic and local economic data, FarmDrive prepares reports to analyze the creditworthiness and solvency of the beneficiary farmers. FarmDrive's alternative credit-risk assessment model, a detailed credit profile tool, provides financial institutions with an agriculturally relevant and data-driven model to assess risk and develop loans that fit the needs of smallholder farmers. Once approved, the loans can be received via mobile money, making transfers even easier. FarmDrive additionally bundles loans with hybrid index insurance and supports financial institutions to create loan products that are more likely to be repaid on time and protected in the event of unforeseen climatic shocks.[55] Between the launch of FarmDrive in 2014 and October 2018, the company had distributed over US$300,000 in loans to Kenyan farmers, 37 percent of whom were young farmers.[56]

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New crowdfunding platforms leverage private capital within and outside farming communities by connecting farmers with potential investors.[57] The funding can be a donation or be made in exchange for a good, as a loan, or equity in the venture. Crowdfunding platforms such as Farmcrowdy enable farmers to access credit directly from a sponsor, who would earn a share of the profit after harvest in return. In fact, the funding systems are a modern and extended version of the more traditional borrowing from family and friends. To scale up the use of

crowdfunding platforms, favorable regulations, modern ICT infrastructure, cultural acceptance and trust between financial contributors and recipients are key.[58] In 2015, 57 crowdfunding platforms existed in SSA.[59]

Farmcrowdy, an award-winning Nigerian start-up, is an online platform connecting potential investors to farmers through a sponsorship model to fund higher yields for a share of the returns.[60] By combining its crowdfunding platform with extension services for the farmers, access to improved inputs, and sales of farm produce for higher value, Farmcrowdy reduces the risk for investors and unlocks previously untapped sources of capital for rural investment. Launched in 2016 and working with partners such as Syngenta and the International Institute of Tropical Agriculture, Farmcrowdy has helped over 11,000 rural farmers expand their farm operations, including rearing 1.7 million chickens, and increase their revenues. The platform has recorded over 35,000 farm sponsorships since 2016.[61]

Enable access to machinery, tools and inputs

Africa is the region with the least-mechanized agricultural system in the world. African farmers have 10 times fewer mechanized tools per farm area than farmers in other developing regions, and access has not grown as quickly as elsewhere.[62] Access to adequate tools, machinery and inputs is often a limiting factor for farmers, not only affecting production, but also the efficiency of the entire food value chain. The uptake and adequate use of agricultural inputs such as improved seeds and fertilizers, irrigation, and small-scale mechanization, including better technologies, are fundamental ingredients for improving yields in African agriculture and implementing sustainable farming practices. Existing and new digital technologies seek to increase the uptake and sustainable application of inputs by bridging the information gap, easing access to finance to purchase inputs or hire machinery, and addressing supplier inefficiencies and market barriers.

Hiring services

ICTs can facilitate smallholders' access to mechanization services, such as tractors. For example, by connecting tractor owners to farmers through IoT, digital solutions can make agricultural mechanization services more accessible and affordable for tractor owners.[63] The "uberization" of the agriculture sector is an innovative approach that lowers the cost of access to tools and machines. It provides viable alternatives to costly subsidy programs and government-run procurement and distribution schemes. There are several platforms offering tractor hiring services as well as other services ranging from plowing, harrowing, planting, spraying, harvesting, and baling to hedge trimming. For example, TROTRO Tractor, a hiring platform in Ghana, connects farmers and tractor operators and allows owners to monitor the movement and work progress of their equipment.

Launched in 2016, **TROTRO Tractor Limited** (TTL) connects farmers with tractor operators through their digital platform. Through SMS, the farmer requests, schedules and prepays for tractor services. In turn, the platform allows tractor owners to monitor the use of their tractor, which minimizes fraud and maximizes machine value. The software also allows owners to track maintenance needs.[64] While the initial startup costs were high, covering visits to farming communities across the country to introduce them to the service, TROTRO Tractor had more than 30,000 farmers in its database as of October 2018.[65] Thirty percent of TROTRO Tractor users are women, who are now able to circumvent the challenge of low asset ownership and collateral by hiring tractors, instead of having to purchase them.[66]

Hello Tractor has developed a technology to increase and optimize tractor activity in Africa by connecting tractor owners to farmers through an IoT digital solution, which bridges the gap between traditional farming and more technologically advanced approaches. The platform simplifies complex data to make tractors profitable as business assets, even in smallholder farming systems. Hello Tractor's technology is an off-the-shelf monitoring device that, when fitted onto a tractor, allows equipment owners to better manage their machines on the farm using an app. Each monitoring device is equipped with an international SIM card, providing GPRS (General Packet Radio Services) and SMS capabilities for data transmission and built to withstand agricultural wear and tear. The monitoring device tracks the tractor, relaying critical information to both home base and the operator, providing 24-hour visibility of tractor assets in the field. If the monitoring device is tampered with or removed from the tractor, the owner is notified immediately. The technology fits onto any brand of tractor to help owners manage machine fleets in the field, minimize fraud and maximize machine value.[67]

Input information and adoption

While information and access to finance can eliminate barriers to input uptake by farmers, digital entrepreneurs in Africa have also sought to reduce market barriers to make suppliers more competitive, transparent and efficient in the provision of their services. Agricultural input supply chains are large, complex and frequently fragmented, involving distributors, retailers, aggregators and farmers—each with their own requirements and agreements. For last-mile farmers in Africa, access to inputs can thus seem mired in logistical challenges, opaque and unclear pricing systems, and high costs driven by inefficient operations. Digital technologies can help to synthesize supplier networks, streamline operations, improve efficiency and transparency, expand market coverage, and tailor offers for local needs.[68,69]

iProcure is the largest agricultural input supply chain platform in Kenya, linking farmers and farmer cooperatives to manufacturers of agricultural inputs. Farmers effectively place a "request for procurement" on the platform, outlining what they require. Multiple suppliers then offer matching quotations, allowing the farmers to select the one best meeting their needs. This replaces the traditional system of buying supplies and reduces the search costs for farmers. Farmers can also create their own trusted supplier networks, which they can manage and evaluate and use to create automated recurring orders and invite their own trusted suppliers to join the system. While suppliers can directly market to buyers who are actively seeking to procure goods or services that they offer. Through accrued efficiencies, iProcure offers farmers discounts of 10 to 20 percent every time they purchase farming products. iProcure also provides business intelligence and data-driven stock management across the supply chains, so suppliers can analyze their market share and real-time critical sales data, growing sales and product performance.[70, 71]

AfricaRice and the Dutch company Co-Capacity have developed a mobile app for tablets and smartphones to provide field-specific recommendations to farmers for best mineral fertilizer application. **RiceAdvice** service providers act as an intermediary to collect farmers' data and interact with the app to generate recommendations on target yields, plant nutrition, crop calendars and good agricultural practices based on available financial resources. In a trial conducted in Mali, Senegal and Nigeria between 2015 and 2017, farmers using the app reported average yield gains of 0.6 to 1.8 tons/ha, while their average income increased by US$100 to US$200/ha thanks to a shift in fertilizer use. Most farmers who used RiceAdvice reported increased yields and incomes and reduced fertilizer use. RiceAdvice appeared to be most useful to public- and private-sector extension agents and NGOs because of persistently low literacy rates and a lack of smartphones among farmers.[72]

At production level

Raise productivity more sustainably

Precision farming

New digital technologies can also help make farming more sustainable and productive while creating new employment opportunities across the value chain. For example, digital technologies can support precision agriculture, aimed at sustainably maximizing agricultural productivity through the targeted use of inputs, such as seed, fertilizer and water. The development of digital hardware for agriculture in the form of sensors, drones, smart irrigation powered by the IoT, and even robotics is disrupting the way that decisions are made and inputs are applied. Sensors placed around the farm or on farm equipment enable farmers to closely monitor the progress of their crops remotely. For example, the sensors can be used to connect to an automated drip irrigation system, making the irrigation process more efficient and freeing farmers' time for other tasks.[73] In general, real-time data and information allow farmers to identify and manage potential problems, even at individual crop level, in a timely manner.

As part of the **Third Eye** project, low-cost drones are being used by extension workers in Mozambique to provide advice to farmers on where and when to irrigate and when to apply fertilizer or seeds. Drones equipped with near-infrared sensors and tailored software can capture and analyze data on the spot. Maps are produced based on the collected information and discussed with bean, maize and rice farmers. More than 2,800 farmers are beneficiaries of the intervention and 71 percent of them are women. The project reaches an area of 1,800 ha where a total of 14 extension workers operate the drones. An evaluation found that crop production had increased by 41 percent, while total water use fell by 9 percent, resulting in a 55 percent water productivity increase.[74]

The development of digital hardware for agriculture in the form of sensors, drones, smart irrigation powered by the IoT, and even robotics is disrupting the way that decisions are made and inputs are applied.

In Niger, the **Tele-Irrigation kit** was developed in 2011 and brought to the market by a private local company, Tech-Innov. The kit consists of a solar station and pump, a water distribution network and a mobile phone. It allows farmers to remotely control their irrigation systems using a mobile phone. Tele-Irrigation also makes it possible to collect and disseminate real-time and remote meteorological and hydrological data, including temperature, soil moisture content, rainfall, solar radiation and wind speed. Famers save time, use water more efficiently and can increase land under irrigation, which in turn may increase productivity and incomes. Furthermore, to compensate for a lack of fodder during the dry season, Tele-Irrigation kits are being adopted to produce fodder in breeding centers, with funds from the Agricultural Productivity Program in West Africa.[75]

Insurance

African agriculture is a risky business, in part because of its continued reliance on rainfall. ICTs can allow farmers to access various insurance products that can protect them against crops losses when damage occurs due to climatic shocks or weather variability. "De-risking" production through insurance subscriptions may incentivize farmers to buy higher quality seeds or invest in fertilizer and other inputs.[76] Moreover, innovations in earth observation, satellite rainfall estimations and remote sensing technology, combined with in situ data, have contributed to the development of affordable insurance services that are adapted to the needs of smallholders.[77]

ACRE Africa, formerly Kilimo Salama, was started 2009 in Kenya and Rwanda. It advises insurers on protection for African smallholders and reduces agricultural production risks as farmers can better cope with unforeseen events and become more creditworthy and able to access to loans linked to insurance. The partnership between Syngenta Foundation, UAP Insurance and Safaricom bundles insurance with loans for seeds, fertilizer and extension services. Eight weather stations broadcast weather updates and measure rainfall amounts; when a station detects rainfall levels that are below or above a crop's rainfall needs, a payout is triggered. Fully automated weather stations connected to cloud-based servers via GPRS and satellites are used to determine payouts. Disbursements are made automatically for each affected farmer within a 15 to 20 km radius as soon as a weather station records too much or too little rainfall. Each affected farmer is informed about the claim and payout through an SMS message, and the payments to farmers are made using a mobile phone-based money transfer, M-Pesa. Since 2014, ACRE reached over 187,000 farmers, making it the largest agricultural insurance program in Africa. Thanks to the insurance, over 30,000 farmers in Kenya were able to access US$5.5 million in financing. In addition, insured farmers invested 20 percent more in their farms and generated 16 percent more income than farmers without insurance.[78]

Zimbabwe's largest telecommunications network provider, **Econet,** developed the EcoFarmer mobile farming platform in 2013 as a weather-index insurance business. By subscribing to this platform, farmers can insure their crops against failed, delayed or excessive rainfall for as little as US$2.50 per year for US$25 worth of coverage, and receive agronomic information via SMS and USSD. In addition, Econet partnered with the Zimbabwe Farmers' Union (ZFU) and Mercy Corps in 2015 to provide the "ZFU-EcoFarmer Combo." A US$1 annual subscription targeted more than one million farming householdsrepresented by ZFU.The EcoFarmer Combo provides farmers with ZFU membership, which includes training on best practices on maize and cattle as well as weather-index insurance to cover maize crop failure for one season.[79,80] By 2018, EcoFarmer had 700,000 registered farmers and over 20,000 farmers had subscribed to the ZFU EcoFarmer Combo.[81,82]

Digital extension services

Smallholder farmers in rural areas often lack access to appropriate agricultural training or extension services. As a result, agricultural practices and farming techniques that could boost yields, preserve the quality of soils, or make the most efficient and prudent use of agricultural inputs are often not being harnessed. Due to poor infrastructure in some of the most remote areas of Africa, reaching smallholder farmers with information on best practices can be difficult, costly and time consuming. As a result, extension services are often not available in a timely manner.[83]

Digitalization can improve the agricultural extension system by providing services at the right time, attaining scale, and facilitating adoption of new agronomic practices, resulting in yield improvements and higher income for farming households.[84] In 2014, a study from Kenya revealed that small sugarcane farmers who received farming advice via SMS right around the time they needed to complete tasks, such as watering their crops, saw an increase in yields by 11.5 percent.[85] In addition, digital trainings can play an important role in reaching farmers directly or through extension workers.[86] This can be particularly important in areas where education levels are low, as mobile technologies can offer new ways of accessing important information through videos, pictures or voice messages.[87] Furthermore, extension agents can be engaged to facilitate the use of and offer complimentary training on ICT-enabled services to smallholders.

Senekela, launched in Mali in 2013, links agronomists with smallholder farmers to provide information and advice on farming practices. The service is offered in French, but also in the local language Bambara. Farmers can receive advice on agricultural production, including planting methods, seeds, time of sowing, and fertilizer use. Farmers can also receive updates on market prices by making a phone call using a SIM card from telecommunications corporation Orange to the center. The service costs US$0.10 per minute.[88]

Pest and disease management

Each year, smallholder farmers across Africa lose yields to pests and disease, causing income loss and threatening farmers' food security and livelihoods. In 2017, maize farmers in six African countries—Ethiopia, Kenya, Rwanda, Uganda, Tanzania and Malawi—incurred an estimated combined annual loss of US$0.9–1.1 billion due to invasive species, with estimated future annual losses of US$1–1.2 billion over the next 5 to 10 years.[89] Timely and location-specific information on pests and disease is essential to reacting as soon and efficiently as possible. Digital technologies such as drones and satellites using aerial imagery and sensors can help farmers by providing them with timely warnings on pests and plant diseases.[90] While these technologies might not be available for all smallholder farmers, the captured data could also be shared via platforms, apps and early warning systems. These warning systems are critical for the prevention of outbreaks as well as for the monitoring of existing pests and diseases through mapping the spread of disease or insects, such as the fall armyworm. Digital technologies can also be applied to the livestock sector as early warning systems, to facilitate access to vaccinations and to respond more quickly to outbreaks of pests and disease.[91]

CowTribe in Ghana was founded in 2016 to deliver animal vaccine and other livestock services and information to last-mile farmers in Africa via a farmer's phone. The aggregated demand for livestock farming inputs and services creates market incentives for veterinarians and suppliers to service rural communities. CowTribe also send SMS alerts to farmers with information on disease outbreaks and offers practical advice. In 2016-17, CowTribe was piloted with 10,000 farmers in 119 communities in northern Ghana and has since scaled up to reach 29,000 farmers. In less than two years, vaccine coverage among CowTribe users has increased from 18 to 65 percent, and early data show livestock mortalities decreasing rapidly—in some communities to less than 5 percent. In addition, farmers using the CowTribe service—many of whom were living on less than US$1 per day—have been able to add an estimated US$300 to their annual household income.[92,93]

At postharvest level

Access to transportation

Estimates indicate that over half of fresh fruits and vegetables produced in SSA are lost or wasted. Nearly half of these losses occur during postharvest handling and processing because of inadequate access to market information, high transportation costs, poor handling and storage, lack of materials, tools, and/or equipment, limited infrastructure for transporting produce to market, and ineffective government regulations.[94,95,96] Improved and more cost-efficient transport systems are essential to minimize the time lag between harvest, processing and retail. Access to efficient transport logistics has been found to increase farmers' income by 10 and up to 100 percent.[97]

Between July 2011 and 2016, the Zambia National Farmers Union operated **Transzam**, an electronic transport system that connected farmers and truck drivers to manage and organize the transport of agricultural products from fields and rural areas to urban centers.[98] Through the system, farmers were able to indicate the size of their load and their collection point, while the transporters returning from the market with an empty truck were able to use the platform to find out where to collect new products to be brought to and sold at a market. In addition, famers were able to directly communicate with transporters registered in a directory using voice message and SMS. Platform users paid an initial subscription fee, although this was waived for the first six months. Some farmers not only sold to markets but also brought products back to sell in their own communities.[99] As of December 2011, Transzam had 91 transporters registered on the system and the number of loads posted on the system was 47. The total weight of all the goods posted on the system to be transported reached over 308,785 tons, equivalent to about 10,295 truckloads.[100,101]

Access to market and price information

Most African farmers still have limited access to real-time information on market prices that would enable them to make sound decisions on when and where to sell their crops and at what prices. Access to price information through digital technologies can increase farmers' negotiating power and limit the risk of selling produce under value.[102] In the rural areas of Niger, farmers using mobile phones decreased the search cost on agricultural price information by half.[103] Across several districts in Uganda, information on prices for some main crops was disseminated through local radio stations, enabling farmers to negotiate higher farm-gate prices on their surplus production.[104] The price for maize at the farm gate increased by up to 15 percent.[105]

In 2011, the RECA (National Network of Chambers of Agriculture of Niger) and Orange Niger launched **Labaroun Kassoua**, a service that provides information on current prices of agricultural commodities and livestock across 70 major Nigerien markets to rural communities. The information improves farmers' decision-making on where to sell their produce or purchase inputs, thereby reducing transport costs to markets and allowing farmers to sell their produce when demand and prices are high. By October 2012, Labaroun Kassoua had registered thousands of (SMS and USSD) connections with mobile phones of more than 8,000 regular unique users. The success of the service incentivized RECA and Orange Niger to start providing audio services in early 2013 using the Interactive Voice Response protocol.[106]

Twiga Foods was created in 2014 to connect small fruit and vegetable farmers in rural Kenya to small and medium-sized vendors in urban cities. Through a mobile-based cashless platform, Twiga can offer higher prices and a guaranteed market to farmers—thus reducing postharvest losses—lower prices and a reliable supply to vendors.[107] Consumers also benefit from prices at up to 10 to 15 percent below the traditional wholesale market for their fresh produce.[108] Twiga employs blockchain technology to keep track of the transactions carried out by its clients. Using its data, the clients can also assess their ability to access loans and other financial products.[109] In addition, Twiga Foods uses M-Pesa to manage and streamline their payment processes. As of November 2018, over 13,000 farmers and 6,000 vendors in Kenya work with Twiga—which pays 20 to 40 percent more than brokers and farmer groups and delivers payment in full within 24 hours through mobile money transactions. This helps farmers anticipate income and aids in financial planning.[110]

Access to storage

ICTs can also contribute to the reduction of food losses along the whole value chain in Africa, including at postharvest stage by improving access to storage technologies and the efficiency of the logistics of transporting crops to market. The lack of proper storage facilities

remains a major cause of postharvest losses in Africa, as facilities either do not exist or are inaccessible to most smallholder farmers. Technological solutions and innovations along the food value chain can help to decrease these losses.[111]

One Acre Fund (OAF), is a nonprofit social enterprise working with more than 500,000 smallholder farmers in Rwanda, Burundi, Tanzania, Malawi and Uganda. OAF provides a wide range of mobile services. These include asset-based credit to invest in high-quality seeds and fertilizer, with a flexible repayment system that allows farmers to pay back their loans in any amount throughout the loan term; access to PICS (Purdue Improved Crop Storage) bags; and training throughout the season on modern agricultural techniques. Since food prices tend to be at their lowest at harvest time, holding onto a portion of harvests for three to four months can dramatically increase smallholders' profits. Maize home-storage loans provided at harvest time help farmers address their immediate spending needs, enabling them to hold onto their grain until later in the season. An evaluation has shown that the loans can lead to a US$27 increase in profit per farmer per season.[112]

At consumption level

Improved nutrition outcomes

While increased food production is key to meeting the food demands of a growing population across the continent, the quality and diversity of the food consumed is just as important. Although the proportion of people who suffer from hunger in Africa dropped from 27.6 percent to 20 percent between 1990 and 2015, the total number of hungry people increased from 182 million to 233 million over the same period, largely due to population growth.[113] Despite visible progress, reducing malnutrition—undernourishment, micronutrient deficiencies, and overweight and obesity—remains a challenge. Limited access to information, particularly among women and vulnerable groups in remote areas, is a major barrier to the adoption of best nutrition practices. Digital technologies can play an important role in increasing awareness and knowledge about nutrition.[114]

mNutrition, funded by the UK Department for International Development (DfID) targets women and young children to change child feeding and dietary practices. The initiative aims to create demand for nutrition and health-related services, establish timely and efficient data surveillance tools for key nutrition indicators, and promote nutrition-sensitive agriculture practices among three million people across 12 countries in SSA and Asia. Examples of the nutrition-sensitive interventions include the cultivation and consumption of crops with higher nutritional value and improved livestock management and consumption of animal-based products. The mHealth service under mNutrition provides relevant, actionable messages via USSD/IVR or SMS (four per month)[115] in Malawi, Ghana, Tanzania, Kenya, Nigeria, Zambia, Uganda and Mozambique.[116] The provision of nutrition information led to an overall average improvement in nutrition knowledge levels by 12 percentage points and an improved nutrition behavior by an average of 13 percentage points. About 81 percent of long-term service users exclusively breastfed their babies for the first six months, while 72 percent of the intermediate users and 69 percent of new users did so.[117]

Improve food safety and traceability

The impact of food safety on health, trade and development is significant. For example, the losses incurred due to aflatoxins alone cost African countries more than US$450 million each year.[118] Improving food safety can lead to better nutrition and health outcomes, reduce the cost of healthcare and confer international trade opportunities. ICTs can help to deliver more efficient and reliable data to comply with international traceability and standards. Examples include QR codes on food items that monitor the safety of food by tracing a product from farm to supermarket check-out. Selina Wamucii, a Kenyan business-to-business platform uses a mobile phone-based traceability system that traces the origin of each package of produce.[119] By tracking and recording information—using digital technologies such as aerial surveillance, sensors and blockchain technologies—about the origin and quality of their produce, smallholder farmers in Africa can distinguish their products, add value and gain access to additional (higher value) markets, both locally and internationally, and participate in certification schemes that can potentially result in higher incomes.[120] Examples include Livestock Identification and Traceability Systems and the Ugandan National Union of Coffee Agribusinesses and Farm Enterprises.

Livestock Identification and Traceability Systems (LITS) can enhance livestock production and trade through improved surveillance, management of infectious diseases, and control of livestock movement. Animal identification and traceability can further increase animal health and food safety. While traditional methods use hot-iron livestock branding, digital technologies use radio frequency identification (RFID) or microchips to track animals. RFID technology, which is inserted into each animal's ear or rumen, can be scanned by handheld readers. A unique identification number on each tag records a full history of the meat's production, distribution, processing and sale, as well as health of the animal.[121] While there are recent trials in the northern Tanzania–Narok–Nairobi trade route,[122] only few African countries (Botswana, South Africa and Namibia) already use the new LITS technology successfully and export chilled and frozen beef to the European Union. The Namibian Livestock Identification and Traceability System (NamLITS) also helped to minimize the impact of a heavy outbreak of foot-and-mouth disease in 2015/16. Using digital technologies, animal technicians were able to accurately track the movement of cattle and detect the exact radius of contamination and possible contamination points to prevent further spread. Strict monitoring and controls minimized the impact of the outbreak, and previously quarantined areas were enabled to export again.[123]

With support from CTA, the **Ugandan National Union of Coffee Agribusinesses and Farm Enterprises** (NUCAFE)—which represents 210 coffee farmers and farmers' organizations in Uganda, totaling 205,120 farming families—has developed a farmer-profiling and farm-mapping system using on-the-ground data, GIS software, spatial data management system, and aerial imagery using drones. An improved database developed using this information generates added value by effectively providing each batch of coffee with a "passport" in the form of a QR code that proves its authenticity and origin. This passport includes information about the farmer who grew the beans, the farmer group, farm location, the product itself, date of delivery to the warehouse, and details of the coffee's subsequent journey along the supply chain. Within six months after its launch in 2017, the initiative had already produced promising results: buyers from Italy and South Korea offered higher prices for coffee produced by the profiled farmers, paying US$4 per kg instead of less than US$2.5 usually paid for untraceable coffee of similar quality. The premium increase of 24 percent on the basic price is directly related to product traceability, which ensures consumers that coffee farmers truly benefit from their purchase and that coffee beans carry specific geological and geospatial quality markers. For a typical Arabica coffee farm of 0.4 ha producing an average of 600 kg each year, this translates to additional annual income of US$961.[124]

Despite certification schemes, the risk of counterfeits and fraud is increasing as food chains become longer and more complex. Information management is thus becoming a challenge for companies seeking to comply with, and respond to, the changing demand. Digital technologies, specifically blockchain technology, can record, hold and disseminate large amounts of data securely and reliably, building transparency among food supply chains.

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4. Limitations and Risks of Digitalization in Agriculture

While digital technologies can play an important role in supporting the transformation of African agriculture, the introduction of new technologies also entails challenges, limitations and risks, particularly with respect to smallholder agriculture and women value chain actors. These challenges, often referred to as the digital divide, need to be considered carefully when devising national agriculture digitalization strategies to ensure that agriculture value chain actors benefit as much as possible from the opportunities of new digital technologies, services and solutions. As discussed in detail in section 5, policies and regulations are needed to close the digital divide, in order to create an environment that allows everyone—including the most remote rural communities—to benefit from new digital technologies.

Women digital empowerment

The use of digital technologies in agriculture can, under favorable circumstances, serve as an important enabler, particularly for youth and women, in all segments of the value chain.[125] However, women tend to use different mobile services than men and are less likely to use IT services or mobile internet. Hence, it is not surprising that the gender gap[i] in the use of mobile internet is a staggering 34 percent in SSA. While the gender gap has narrowed in most regions since 2013, it has widened in Africa. In 2017, women in SSA were on average 14 percent less likely to own a mobile phone than men,[126] and 25 percent less likely to have internet access.[127] This severely constrains the use of mobile phone services and digital technologies that could otherwise facilitate access to information on farm-related activities, nutrition and health, financial support or reaching higher-value markets. It also lowers women's market access and bargaining power and limits their influence and decision-making power in their communities, while deepening their dependency on manual labor or intermediaries. According to the Food and Agriculture Global Practice at the World Bank, equal access to digital market services can increase agricultural production in low- and middle-income countries by 2.5–4 percent and potentially decrease the number of hungry people by 12–17 percent.[128] But without a clear focus on including and serving the poorer segments of society and marginalized people, digitalization and its applications will neither reach nor serve them.[129]

In addition to the gender divide, the rural divide and the digital divide – known together as the triple divide – are further limiting women's access to modern ICTs, particularly in rural areas. Income and education levels, as well as low awareness and cultural barriers are other factors significantly determining mobile phone ownership and the use of mobile internet, which can lead to women bypassing technology and further marginalize female farmers and increase the gender gap. To overcome these challenges and to lower the entry barriers women face to digital technologies and mobile services, digital ecosystems need to be created that target the specific constraints and needs of female agriculture value chain actors. For example, new digital services can provide specialized advice to women running agribusinesses and help them strengthen their links to markets and increase technology uptake. One example from Ghana showed that by increasing women's access to international markets and links to buyers through mobile technologies in the shea nut butter sector reduced the dependency on middlemen and led to an 82 percent increase in profits among women farmers.[130] A study from Uganda underlined that female ownership of mobile phones, increased household incomes and social welfare more than male mobile phone usage alone. This may be partially explained by lower transaction costs through better access to information that improves women's bargaining position within the household.[131]

Hence, access to mobile internet and digital technologies can help to reduce persistent inequalities and improve the livelihoods of women and girls. However, access to ICTs alone will not close the gender digital divide. Proper design and implementation of bottom-up participatory approaches at the community level will be needed to reduce the potential for information inequality. Overall, closing the gender gap will require concerted action by all stakeholders, including the mobile industry, government and women's groups, and targeted policies that ensure women are not excluded from agricultural digitalization, and profit from the potential benefits of ICTs.[132,133]

i The gender gap is a calculation based on the difference between the share of male and female mobile owners/users divided by the share of male mobile owner/users and expressed in percent (GSMA, 2018).

Accessibility

Last-mile infrastructure

The digital divide between Africa's urban and rural areas is particularly striking. It is driven primarily by limited or no access to electricity, weak networks, poor basic connectivity and low digital literacy, which result in substantial differences in telephone and internet penetration. An example from South Africa shows that internet use in some rural areas in the Eastern Cape's communities was just 25 percent in comparison to over 75 percent in Gauteng and Cape Town.[134] In Nigeria too, a majority of rural dwellers near the Niger Delta had very limited access to modern information technology such as telephones (2.7 percent access) and no access to the internet, information centers or libraries, largely because digital technologies were not available in rural areas.[135] Sound digital infrastructure that provides basic connectivity and affordable internet is a prerequisite for smallholder farmers to fully harness the opportunities of digitalization in agriculture.

Digital literacy

Persistently low digital literacy rates, particularly in rural areas, continue to prevent the uptake of digital solutions for agriculture. Agricultural producers across Africa are predominantly low-income smallholder farmers, any of whom are older and often less technologically adept than the younger and urban population. Knowledge and ICT skill development play an important role in understanding digital services even when provided in the right language. In 2015, 28 percent of women and 22 percent of men in Kenya perceived limited technical literacy as a main barrier to owning and using a mobile phone.[136] As discussed in more detail in section 5, improving digital literacy skills through training, integrating digital literacy in school curricula, digital hubs and information centers is therefore critical for establishing an enabling digitalization environment.

Electricity

Constant, reliable and affordable electricity is imperative for almost all aspects of digitalization, including charging phones, operating wireless networks and data centers, or manufacturing of ICT hardware.[137] In 2016, however, only half of Africa's population had access to electricity, while the share of people with access was substantially higher in urban areas at 76 percent.[138] Globally, Africa (excluding South Africa) has one of the lowest rates of electric power consumption per capita/year at 874 kilowatt hours (kWh), compared to 13,000 kWh in the United States and 6,500 kWh in Europe.[139] Furthermore, Africa's electricity demand from agriculture is expected to double from its current levels to about 9 gigawatts (GW) in 2030. The estimated incremental demand between 2015 and 2030 is 4.2 GW.[140] Yet, even where there is access to electricity grids, power outages lead to loss of output, charging costs might be higher or farmers have to travel further to access power. Electricity is therefore a crucial precondition for successful digitalization across all sectors of the economy, including agriculture.

Without improved access to electricity, farmers' access to and use of digital technologies will remain limited.[141] However, combined solutions offering solar-powered charging points with WiFi connectivity are becoming more common across Africa. Examples include the Shiriki Hubs in Rwanda[142] and Microsoft's Mawingu project in Kenya.[143]

Network coverage

In 2017, the number of SIM connections in SSA was about 747 million, representing a 75 percent penetration rate.[144] In comparison, the Asia Pacific region and Latin America had penetration rates of 102 percent and 104 percent, respectively.[145] However, many of the more advanced mobile technologies rely on access to the internet, and although the share of people having access to the internet increased from 23 to 59 percent between 2014 and 2017 in SSA, the share actually using the internet is much lower than elsewhere worldwide. Forty percent of the population in SSA did not have access to the internet at all in 2018, and only 21 percent were actually connected, meaning they actively used the internet.[146] Furthermore, the type and speed of internet connection available in SSA is lagging behind. In 2018, 60 percent of coverage was on 2G, 36 percent on 3G, and just a small fraction—4 percent—was covered by 4G. In comparison, Latin America has a 43 percent 3G coverage and a 23 percent 4G coverage, while Asia Pacific has a 25 percent 3G coverage and a 34 percent 4G coverage.[147] Slow internet speed can hamper productivity and business growth and limits the ability of users to access particular internet-based services and websites.[148]

To overcome poor coverage in remote areas, Facebook trialed solar-powered drones to provide internet access to remote African communities. Although the company intended to disclose blueprints for its drones and other internet devices, the program was terminated in June 2018 largely due to slow progress in fine-tuning the technology.[149] Similarly, although not yet operational, Google's Project Loon is testing aerial balloons to provide internet to remote communities. The network of balloons relays high-speed internet from a ground source to the users. Each balloon is as large as a tennis court, floats at up to 18 km above the Earth's surface, and a network can cover up to about 5,000 km^2. They are currently

being tested in South Africa and Kenya.[150] Furthermore, in February 2019, plans were announced at the Mobile World Congress in Barcelona to establish the continent's first live 5G network in South Africa, the world's first 400 Gbps network in Kenya and a 750 km fiber optic network in Nigeria's Edo and Ogun States.[151]

Affordability and suitability of technologies

Broadband connection and fees

High prices have a significant impact on the uptake and use of internet and mobile services among smallholder farmers. Although the price for mobile internet in Africa has dropped by 30 percent since 2015, the continent still has some of the highest prices for internet use globally. In 2017, Africans spent almost 9 percent of their per capita incomes on 1 GB of internet, compared to 1.5 percent and 3.6 percent in Asia Pacific and Latin America and the Caribbean, respectively. Further, prices varied greatly across the continent, ranging from 0.3 percent in Egypt to 33 percent in Zimbabwe. Currently, only four African countries—Egypt, Mauritius, Tunisia and Nigeria—are on track to meeting the United Nations (UN) Broadband Commission's 2025 target[152] of 1 GB of data costing no more than 2 percent of average monthly income.[153]

> ***Sound digital infrastructure that provides basic connectivity and affordable internet is a prerequisite for smallholder farmers to fully harness the opportunities of digitalization in agriculture.***

Handset prices

Given the low use of personal computers, laptops and tablets, particularly in Africa's rural areas, smartphone ownership offers a great opportunity for accessing the internet and can enable the use of digital technologies and services.[154] While mobile phone penetration in Africa has skyrocketed over the past years, the adoption of smartphones remains low, especially in rural areas. Mobile phone ownership in SSA was 75 percent in 2017, while smartphone ownership was just 34 percent, albeit up from 20 percent in 2014.[155] And although the rate of smartphone adoption is likely to double by 2025, affordability and prices of handsets are a major limitation for smartphone ownership, especially in rural areas.[156]

According to the Mobile Connectivity Index (MCI), which measures the performance of four key enablers of mobile internet connectivity—infrastructure, affordability, consumer readiness, and content and services—African countries perform the worst globally on affordability of handsets. In comparison, the scores for Asia and Pacific, Latin America and Eastern Europe were at least 25 percent higher.[157] However, affordable smartphones are increasingly being made available across the continent by companies including China's Shenzhen Transsion Holdings, whose mobile phone sales account for about one-third in the SSA region.[158] Recently, plans to produce an affordable and high-quality African smartphone were announced by the African Development Bank (AfDB)—the MaraPhone—which will be manufactured in South Africa and Rwanda. The phone is designed to be sold to a local market, although there are plans for it to be exported and sold in Europe.[159] The first factories have been built and production was set to begin in April 2019.[160]

Accuracy and suitability of information

Harnessing and benefitting from mobile technologies relies on the accuracy and the way information is provided. For example, while access to meteorological weather data or real-time farming advice can allow smallholder farmers to protect themselves against adverse weather conditions, information must be provided in a timely manner and must be accurate and localized. To make full use of digital technologies and services, it is crucial that any services and solutions provided to farmers are easy to understand, localized, and meet farmers' actual needs. Traditionally, information sharing, especially in rural areas, happened through personal contacts and exchange among farmers and their communities.[161] One challenge is therefore to build farmers' trust in the reliability of new digital technologies and services. This can be addressed by integrating farmers more actively in the development of new technologies and mobile services—as the MasterCard Lab for Financial Inclusion did in applying human-centered design with its 2KUZE platform[162]—and by ensuring that accurate information is disseminated in a way that benefits farmers.

Risks

Digitalization and big data offer many opportunities for Africa's agricultural transformation. Yet, in addition to factors limiting the uptake of digital technologies

and services, there are several risks associated with digitalization of the agriculture sector that governments need to consider as they embark on developing and implementing their countries' agriculture digitalization strategies.

Automation and employment

As pointed out in the Malabo Montpellier Panel's 2018 report on agricultural mechanization[163], digital technologies ought to be designed in a way that enables social and economic progress, particularly for those living and working in rural economies, both on and off the farm. However, under some conditions, agricultural digitalization may cause an increase in rural unemployment. As prices for digital technologies are decreasing worldwide, automation and computerization may cause an increase in unemployment if the number of workers replaced with machines is greater than the number of jobs created. Lower prices for agricultural automation, including harvesting robots in developed countries, could also lead to a shift of agricultural production from developing countries and a fall in wages.[164] To harness new employment opportunities generated through digitalization, particularly for young people, training and ICT skill development will be essential. New employment opportunities will include the design and development of software and hardware, maintenance and repair of ICTs including handsets, drones, and sensors, and data analysis.

Ownership rights and privacy protection

Open data on agriculture and nutrition can play an important role for innovation and increase transparency, accountability and efficiency across agribusinesses. However, open data also has associated challenges and risks, in particular with respect to data ownership. As an increasing number of digital services use and collect personal data, data privacy laws and data ownership regulations are urgently needed. Most African mobile technology users have little or no recourse if a data breach occurs, as legal and regulatory safeguards often do not exist. Furthermore, most ownership rights accrue to the intermediaries that invest in databases, and not to the farmers providing the data or the users.[165] In 2018, 23 African countries had data protection and privacy legislation in place[166] and only 11 countries have signed the African Union's convention on cybersecurity and personal data since 2014.[167] While open data platforms are highly encouraged, laws and frameworks for governing open

data need to be in place. Without regulation, data can be freely used and shared with third parties, jeopardizing the safety and privacy of smallholder farmers while further marginalizing them.[168] At the same time, smallholder farmers and other agriculture value chain actors, especially those with very limited or no experience with digital services, will have difficulty understanding the implications of having their data collected.[169] While data collection in Africa is largely unregulated, its use and storage is equally lenient, putting farmers at risk.[170]

Intellectual property

Intellectual property (IP) includes patents, trademarks, copyrights, registered designs, know-how, and database and software rights. Protecting IP in a digital world is a major challenge, especially for tech companies and smaller start-ups.[171] With increased access to broadband and ICT development, cybercrime and software piracy are on the rise. In 2017, the share of unlicensed software in Africa was 50 percent higher than the global rate, with countries like Libya and Zimbabwe showing the highest shares of unlicensed software worldwide.[ii,172] While it can be argued that more flexible intellectual property rights (IPR) could be beneficial for developing countries in the short-run, the protection of IP is necessary for the competitiveness of small businesses and start-ups, including in the agriculture sector.[173] IPR tools can help raise farmers' incomes, enhance agrobiodiversity, and reward farmers for their innovation. On the other hand, patents may also restrict farmers from selling, increase costs of seeds, and contribute to the erosion of plant genetic diversity and associated knowledge. Hence, IPR tools may well be a component of an enabling environment for small-scale farmer innovation but other policies and regulations will be needed to reflect the realities of local seed sectors and recognize the contributions of smallholder farmers to agricultural innovation.[174]

Increased investments need to be made to learn from the successes and failures of individual programs or technologies and to highlight gaps and opportunities for further skill development and capacity strengthening.

Increased investments need to be made to learn from the successes and failures of individual programs or technologies and to highlight gaps and opportunities for further skill development and capacity strengthening. Digital applications and services also need to meet quality standards. Research centers can thereby play an active role in the evaluation and impact assessment of specific digital technologies and e-services in rural areas.

ii In 2017, the share of unlicensed software globally was 37 percent, while the Middle East and Africa region had a share of 57 percent. Libya had a share of 90 percent; Zimbabwe a share of 89 percent (Business Software Alliance, 2018).

5. The Enabling Digitalization Environment

The need for an enabling digitalization environment

As described in Sections 3 and 4 of this report, digital agriculture presents new opportunities, but also poses risks to agriculture value chain actors. As agri-food systems and farming become increasingly knowledge-intensive, the necessary institutions and support systems, especially extension, advisory and capacity development services, need to be in place to facilitate digitalization for the benefit of smallholder farmers and those living and working in Africa's rural areas. Rapidly emerging new technologies and technology-based services and solutions also require new capacities and skills among farmers and the institutions that work with them.[175]

The speed and effectiveness at which an agricultural system transforms to become more data- and technology-driven is largely dependent on an enabling institutional environment that allows and encourages data and information to be managed, used, shared and exchanged effectively, equitably and fairly. This environment spans governments, farmers' associations, financial and research institutions, and training centers, policies, regulatory frameworks as well as information and communications-related infrastructure. Crucially, enabling policies are required that allow, and in fact, catalyze investment in the backbone infrastructure that will permit rural populations to overcome their geographic, social and economic isolation.

Africa now has the opportunity to leverage the potential benefits of digitalization and to avoid the pitfalls that digitalization can pose. To do so will require concerted action by governments and the private sector—including smaller start-ups and large private sector companies—as well as agriculture value chain actors and farmer organizations to build a sound digitalization environment that ensures that smallholder farmers and Africa's rural areas are not left behind. National digital agriculture strategies and action plans are required that can serve as a blueprint to transform all sectors of the economy.

More broadly, the role of science, technology and innovation (STI) has been anchored in the African Union Science, Technology and Innovation Strategy for Africa (STISA-2024) adopted in 2014.[176] It is the first phase of a 10-year strategy that places STI at the center of the African Union's Agenda 2063. The strategy aims to address the challenges that hinder development in critical sectors such as agriculture, energy, environment, health, infrastructure, and water. Under priority area #3 "Communications and physical and intellectual mobility," member states commit themselves to invest and create an enabling environment by building a digital infrastructure across all sectors, and to use ICTs to enhance communication between key actors. Implementation of STISA–2024 will take place at three levels—national, regional and continental levels.[177] Furthermore, in February 2019, the African Union recognized digitalization as a top priority for achieving the ambitious goals under its Agenda 2063[178] while a new flagship program of the African Development Bank (AfDB)—ICT4Ag—is being initiated to support the growth, outreach and impact of ICT and agtech solutions. AfDB's intervention areas under this flagship aim to create an enabling environment for digitized agriculture; to establish information systems for enhanced productivity; to promote smart agriculture; and to build digital literacy and capacity. Pilot projects are planned for Morocco and Rwanda. These intervention areas should ultimately better connect farmers to markets and enhance their competitiveness.

As discussed in the next section, various factors create an enabling digitalization environment. In addition to commitment at the highest level, regulatory frameworks, strong digital literacy skills, and supportive digital infrastructure are needed, while access to reliable data will help governments make better informed policy decisions. For example, until now, most collection of agricultural data in Africa has been done manually. The use of the IoT can automate the generation of large amounts of data, increasing reliability and enabling easier and faster analysis.[179]

Elements of an enabling digitalization environment

An enabling digitalization environment is characterized by seven key elements: regulation for the use of digital technologies; fiscal incentives to encourage an environment in which the private sector can leverage its innovation capacities; an emphasis on skills development to improve digital literacy; research and development; last-mile infrastructure to connect those in the most remote rural areas to ICT services; the creation of information and innovation hubs that stimulate the generation of new ideas and solutions for the use of ICT along the food value chain; and South-South cooperation.

Regulation

In the fast-moving reality of digitalization, existing regulatory frameworks designed for traditional products and services may no longer be suitable as countries across Africa start embracing a digitized agriculture sector and a digital economy more broadly. In some cases, existing regulation may even prevent or slow the development of new digital products and services. Conversely, new or updated policy and regulatory measures might be needed to enable digitalization, to drive investment in infrastructure, facilitate innovation, reach into rural areas, and protect citizens from potential misuse of their personal data.

Africa's digital sector is relatively young, albeit growing at breakneck speed. According to the AfDB, the telecommunications sector garnered the largest share (74 percent) of private investment between 1990 and 2013.[180] Therefore, it is essential that regulation develop in tandem, serving not only to support this growth, but also to protect the interests of consumers.

A critical constraint to expanding the uptake and use of digital technologies and services in Africa's agriculture value chains is the poor state of telecommunications infrastructure. To overcome the economic and competition barriers implied in these capital-intensive investments, governments across Africa are looking to develop smart, flexible and friendly regulatory frameworks to attract investments from domestic and international private sectors. Several countries including Kenya, Nigeria and Morocco have chosen to open their telecommunications sector to stimulate foreign investments. Liberalizing the sector in this way has allowed companies to separate infrastructure networks from services provision and develop innovative models for expanding service provision and coverage, leading to a fall in costs for consumers. Liberalization has also allowed new operators—small and medium-sized businesses—to enter the market and develop products that are tailored to market demand.

Substantial challenges still exist in African regulatory systems to steer and sustain the flourishing digitalization industry. African licensing regimes, competition and fair-use guidelines, and cybersecurity as well as environmental laws for digital technologies are being overhauled to keep up with the pace of structural changes in the telecommunications sector, as well as the impact of rapid digitalization in African societies.

While digitalization is credited with connecting remote and otherwise-marginalized communities to services that were previously inaccessible to them, it is also evident that connectivity in many African countries remains persistently strongest in urban centers. Carefully developed regulatory systems could also drive investments in geographical regions and segments of society that were not previously connected.[181] To enable the growth of businesses that are creators of technology, not only consumers of it, regulations and guidelines can nurture local innovation industries for both hardware and software development. For instance, Nigeria has implemented policy guidelines requiring that at least half of personal computers and half of internet-enabled devices in use within Nigeria be made in Nigeria. Similar guidelines are also in place for software development. Not only does this policy aim to encourage job creation and skill development, it also reduces the pressure on foreign exchange.[182,183] Once new technologies have been created, an effective intellectual property system would enhance their competitiveness domestically and internationally and ensure that entrepreneurs gain the maximum benefits from their innovations.[184]

For imported technologies, regulations are useful to define quality of imports, specify their fair and legitimate use, and protect end-users from violations of privacy and misuse of their data. Rwanda adopted performance-based regulations in 2018 for all drones operating within the country to ensure that they meet pre-determined benchmarks, for example for safety thresholds.[185] Although several countries are currently deploying drones in agriculture, only 26 percent of African countries have unmanned aerial vehicle (UAV) regulations in place. No doubt developing suitable regulations for the use of drones in agriculture will require close cooperation among the relevant national civil aviation authority, ministries of ICT, agriculture, and even defense, and drone manufacturers. Importantly, because drones can travel across borders, regulations for their use in agriculture will call for harmonization across regions.[186] At the other end of the spectrum of innovations, modern ICT technologies can contain multiple chemical elements and precious metals, as well as plastics, glass and ceramics. Effective regulations on safe disposal of technologies on the continent are urgently required to prevent environmental damage. There is untapped potential in Africa for recycling technology and developing a circular economy for new innovations.[187]

While data collection and analysis can empower the agriculture sector and smallholder farmers by making information available on current trends, predicting future opportunities, and even devising modern marketing strategies, legislation is essential to create a regulatory environment that promotes an innovative and confident use of technologies and e-services. A balance must be struck between the free-flow of data and information and privacy policies. This is particularly important as large amounts of information are collected and stored.

Regional regulations for data privacy and use are already in place, including the AU's Convention on Cybersecurity and Personal Data Protection; Southern African Development Community (SADC) Model Law on Data Protection; Supplementary Act A/SA.1/01/10 on Personal Data Protection Within ECOWAS; and the East African Community's Framework for Cyberlaws. Despite these advances, the implementation of these laws to regulate the collection, control and processing of individuals' data, as well as legislation at the national level, is lagging.[188]

Financing for digitalization

One of the biggest obstacles to expanding infrastructure, including last-mile infrastructure, for a digital transformation of the agriculture sector and to bringing to scale successful, proven technologies remains access to finance. Most farmers still depend on their own savings to invest in agricultural tools and technologies, mobile phones and, where it is available, internet access. The significant upfront costs associated with technology adoption as well as limited last-mile infrastructure means that many services and information available through digitalization remain beyond the reach of smallholder farmers, at least for now. In addition, the cost for internet and mobile handsets across the continent is not on par with the rest of the world. Given the potential benefits that agricultural digitalization can offer to smallholder farmers and other actors in the agriculture value chain, concerted efforts to remove financial constraints to expanding digitalization are key for an agricultural transformation and must be a top priority for African governments.

Setting up these technologies requires not only a supportive fiscal regime where barriers to market entry are removed, but also one that enables cooperation among the innovators and the finance sector. For instance, launching M-Pesa in Kenya was not without its challenges. Established banks resisted the entry of a new financial service provider (Safaricom/Vodafone Group), which did not face the same licensing or regulatory compliance requirements that they did. In fact, M-Pesa's agents would rely on infrastructure constructed by the banks, such as ATMs and branches, to deposit and withdraw cash. Although the product was clearly filling a gap in the financial services market in Kenya, and was well received by the customers, M-Pesa had highlighted the gap in Kenya's regulatory framework. With the uncharted territory, the Central Bank of Kenya was forced to review its own regulations and other finance bills relevant to payment services to enable M-Pesa to operate in Kenya.[189]

At the same time, it is critical that farmers be able to access finance for equipment and services and that a supportive environment for micro-credits and hiring arrangements be facilitated. This can be done by lowering sales taxes and minimizing barriers such as import duties on technologies and tools and spare parts for local manufacturing. Such a fiscal regime would initially facilitate the import of technologies until local markets are developed. Moreover, increased and sustained investments by governments and the private sector need to be made in supportive and last-mile infrastructure. Long-term finance urgently needs to be made available to shoulder the high cost of financing the last mile of fiber optic, even in densely populated, prosperous urban areas.

The private sector will play a key role in financing innovation and in the digitalization of Africa's agriculture sector. Private sector accelerator funds are already playing a key role in speeding up development of promising technologies and solutions in the food and agriculture sector. Innovation funds in the agriculture sector serve to strengthen innovation-promoting links between public institutions, private entrepreneurs, and other actors, such as farmers groups. These funds—often in the form of grants—create platforms for innovative activity by providing incentives to improve collaboration and quality of services offered.[190] Between 2016 and 2018, US$19 million was invested in agriculture technology in Africa, as agtech startups grew 110 percent.[191] The private sector

can also contribute through service provision, technology development and commercialization, or through other business-related innovations. The private sector contribution needs to be accompanied by long-term public investments in rural credit and markets, creating synergistic effects. Combined long-term sustained public investments in infrastructure, skill development, and R&D can facilitate or stimulate private investment.

Digital literacy readiness and skill development

Building human capacity will be crucial to building digital literacy readiness across the food system. Evidence shows that countries south of the Sahara continue to reap low benefits from digitalization,[192] while experience from other regions indicates that Africa urgently needs to develop a targeted approach to strengthening digital skill development and digital literacy readiness, including policies to encourage innovation and entrepreneurship to meet local demand. Greater digital literacy and skills are essential to harness the opportunities presented by a digitalized agriculture sector. Skill development and digital readiness needs to be strengthened at three levels: Farmers and other agriculture value chain actors will need digital know-how to interact with what the digital world can offer. Helping agriculture value chain actors build and strengthen their abilities to use digital services and solutions will be particularly important, and should go hand-in-hand with a drive toward building more farmer-centric and locally applicable products. At the next level, digital entrepreneurs will need specialized coding and programming skills to build online businesses and to design and develop new software and hardware. Startup ecosystems can develop these skills and help connect local entrepreneurs with wider, global networks and capital through incubators, accelerators and hackathons. Studies show that there is rising excitement among African start-ups around the power of accelerators to boost human capital.[193] Finally, governments must take the lead in developing and training their employees—from the senior-most officials to local extension agents—to understand and use digital tools and solutions and how to deploy them in various government initiatives. Government officials need the knowledge to make use of big data to improve the services governments can offer to smallholder farmers and rural communities as well as to improve their policymaking for the benefit of smallholder agriculture.

Farmers and other agriculture value chain actors will need digital know-how to interact with what the digital world can offer.

The so-called Fourth Industrial Revolution is having a disruptive effect on African economies and the development of digital skills is vital to harness the opportunities that digitalization presents for rural communities. There is an opportunity now across Africa to embrace new and cutting-edge technologies combined with human talent to accelerate agricultural transformation and economic growth. Ongoing education, skill development and training for all actors along the agriculture value chain, including the rural and urban youth, will have a positive effect for both businesses and economies as a whole. A strong pipeline of talent with the relevant skills and knowledge is beneficial to governments and businesses, while it allows young people to advance into employment opportunities with increased economic rewards.

The key for Africa will be to adopt an innovative mindset and focus on skill development to ensure that digital transformation opportunities can be filled—and led—by Africans. It will also mean that now, more than ever

before, Africa must become a creator, and not just a consumer, of technology. The public sector in cooperation with the private sector and start-ups needs to lead the way, setting the example for an inclusive agricultural transformation that benefits all, but particularly young people and the next generation of "agripreneurs."

Crucially, whether Africa's fast-growing young population will become a dividend will depend on what governments and their partners have to offer in terms of policies, strategies and programs aimed at not only providing African youth with the skills and tools for employment and leadership, but also creating the enabling environment for self-employment and entrepreneurship. Universities across Africa should expand their curricula to include programming and algorithm design to become hubs for serving digital innovations in the food system, accompanied by technical and vocational education and training (TVET) to equip young people with the digital skills needed to efficiently use and develop new agricultural technologies and digital services. In this context, in 2018, an African Ministerial Forum on "Youth skills and enterprise in the digital age" brought together senior policymakers, development partners, private sector, representatives of African youth, young entrepreneurs and civil society in Tunisia.[194] The aim was to showcase, share and discuss comprehensive and innovative TVET models and programs aimed at developing the leadership and digital skills of the youth and equipping them with the necessary knowledge and tools to design marketable products and services and, therefore, create sustainable enterprises and generate employment. In Rwanda, a number of efforts have been made to advance digital skill development. Knowledge Lab (kLab) is an "open technology hub" that supports entrepreneurs with mentorship and through networks.[195] And Carnegie Mellon University (CMU) Africa in cooperation with the MasterCard Foundation has developed master's degrees in electrical and computer engineering and information technology to train the next generation of technology leaders and entrepreneurs in Rwanda since 2016. CMU Africa is a public-private venture of the Government of Rwanda and CMU Pittsburgh and part of Kigali Innovation City.[196]

Governments must take the lead in developing and training their employees—from the senior-most officials to local extension agents—to understand and use digital tools and solutions.

Research and development

Skill development will also be crucial in the context of developing a flourishing R&D ecosystem to design digital solutions for the agriculture sector. Digital technologies, AI, the IoT and other ICTs—by producing and accumulating vast amounts of data—provide an opportunity to monitor, analyze, evaluate and improve existing digital solutions while developing new ones. This is not only relevant for agriculture value chain actors, but also equally essential for start-ups, private companies and governments in order to continuously innovate and improve. Sustained long-term investments and dedicated institutions that allow for a thriving R&D ecosystem are urgently needed to design and develop locally adapted, sustainable tech solutions that build up Africa's agtech sector and create new opportunities particularly for the continent's youth.

Digital infrastructure

Digital infrastructure refers to the extent to which a country has invested in ICT infrastructure that is required to support a digital economy. As discussed in detail in section 3, this includes access to and use of infrastructure, as well as its affordability for the consumer. Specifically, it refers to access to international bandwidth, mobile-network coverage, internet and mobile-phone penetration, and the costs of broadband and mobile-phone access. Although several African countries have embarked on the path toward a digital economy, more needs to be done to better connect countries, to provide universal access to the internet, and enable easier smartphone penetration.[197] The lack of connectivity creates limitations around the penetration of more modern applications and uses for mobile technology. There are, however, signs of progress across the continent: countries like Kenya have moved toward creating services to facilitate more inclusive infrastructure for the population. Senegal has set a target of generating 10 percent of its GDP from the digital economy by 2025. Rwanda has rolled out 4G and fiber connectivity to deliver online e-government and other services across the country.

Underpinning all this is the need to close the digital divide by ensuring that rural communities are well-connected to reliable sources of electricity and last-mile infrastructure, as well as a reliable internet connection at household level, schools and workplaces. The World Economic Forum's *Global Information Technology Report* of 2015 differentiates between two types of initiatives

taken by governments to expand inclusive internet use: Those that facilitate investments in networks in existing and new areas. These may be urban or rural, but mostly urban. And those that comprise plans and projects that increase the unconnected population's demand for internet services.[198] In many places across Africa, a vast digital divide continues to exist between well-connected urban centers and off-the-grid rural areas. More needs to be done by governments in cooperation with the private sector to build and improve last-mile infrastructure that reaches those in the rural and most remote areas and allows them to harness the opportunities of new technologies.[199]

Innovation hubs

In recent years, intermediaries such as technology innovation hubs and incubators have been playing a crucial role in developing and shaping local and regional digitalization environments, particularly in urban centers. In 2018, there were 442 tech hubs across the continent[200], up from 314 in 2016, and an increasing number of international investors are showing eagerness to invest in tech-related start-ups and innovation hubs. In 2017, 159 African tech start-ups received investments worth a total of US$195 million, up from 146 in 2016 and 125 in 2015. While most investments are still targeted toward financial tech, investments in agtech related start-ups and technologies showed the fastest growth in investments, at 203 percent in 2017.[201,202]

Many promising examples of digital and technology start-ups in Africa also highlight their positive impact within the traditional public sector areas and responsibilities. These start-ups and entrepreneurs are filling important gaps by focusing on improving services that have so far been only partially addressed by governments or the private sector, such as making financing accessible to farmers outside large financial institutions. Governments and larger private sector companies need to actively seek out innovative forms of public-private partnerships to maximize the impact of these new technologies and digital services. And although there are now innovation hubs and incubators in more than 93 cities in 42 African countries, half of them are concentrated in just five countries—South Africa, Egypt, Kenya, Nigeria and Morocco.[203]

For example, Kenya's Youth Agribusiness Strategy (KYAS) 2017–2021 strongly promotes the role of digital technologies to provide new opportunities for youth in agriculture and its value chains. To attract more youth into farming and related activities, to drive agricultural innovation, research and technology development and deployment, KYAS has allocated nearly US$20 million for 2017-2021 to building capacity of youth by creating knowledge and information hubs and resource centers within Kenya's

counties, as well as related tech-labs and ICT centers and mobile apps. To provide access to markets for outputs, KYAS will support the formation, review and integration of structured information platforms and infrastructure.

South-South cooperation

Although Africa's portfolio of agricultural digitalization is clearly building rapidly and comprehensively, collaboration with peers from the global south could magnify their impact. SDG 17 promotes a strong commitment to cooperation, particularly on improving access to technology and knowledge as an important way to share ideas and foster innovation. Over the last decades, South-South cooperation has evolved to include technology transfers, knowledge exchanges, financial assistance and concessional loans.[204,205]

The latest partnership agreement between China and Africa—the China-Africa Cooperation Beijing Action Plan (2019–2021)—outlines clear opportunities to leverage the strengths of each party to maximize the impact of digitalization in agriculture.[206] Although China has invested in Africa's agricultural transformation since 2006 through Agriculture Technology Demonstration Centres (ATDCs), they have achieved limited, often short-lived and localized success. Moreover, the ATDCs have not included digital technologies within their design, focusing instead on improved seed and machinery transfers.[207] This bilateral partnership would benefit from including more private enterprises in digital technology transfers.

Similarly, there is significant potential for both India and Africa to cooperate on ICTs for agriculture in Africa.

India is already a large investor in Africa, particularly on farmland acquisitions. It also has a dynamic digital sector domestically, which is now being deployed internationally to develop infrastructure across Africa. Further investment from India's private sector can be directed at hardware innovations such as drones, sensors and GIS technology, as well as platform-based ICT tools such as web-based information systems, SMS-based services and mobile apps. To maximize the reach and impact of these interventions, these investments must come with training and capacity building for farmers through extension services, and perhaps through programs that introduce technologies to farmers on a trial basis.[208]

Digital Green is an agricultural information dissemination project working with smallholder farmers across the world. Established in India in 2006, Digital Green has been working in Ethiopia since 2011 with partners to promote the adoption of improved agricultural technologies and practices as well as nutrition practices through its video-based extension approach. In partnerships with the Ministry of Agriculture and Natural Resources and the Ministry of Agriculture and Livestock's Agriculture Extension Directorate, Digital Green has implemented four programs that leverage peer-to-peer learning via video, radio and interactive voice response.[209] Because the content is developed using a participatory process and local extension agents are trained in dissemination, there is greater uptake of the recommendations. An independent mid-term evaluation of its pilot project "Connect Online–Connect Offline" (COCO) platform concluded that 42 percent of participating farmers had adopted quality protein maize for household consumption, 45 percent had adopted improved health practices including antenatal care, improving childbirth, reducing maternal mortality and morbidity, and improving postnatal care, and 25 percent had adopted a line planting method for teff, wheat and maize.[210]

Informing better policymaking

Through new technologies, including the IoT, digital cameras, AI, satellites, sensors, and communication devices sending and receiving data over the internet, large amounts of data are collected and analyzed each day. This can enable better and quicker decision-making, evaluation and development of monitoring frameworks. Big data is already being used widely across Africa. The Open Data Impact Map identifies four types of organizations making use of big data in the context of African agriculture. These include companies, non-profit organizations, academic institutions and developer groups that use open data to provide solutions that better inform farmers' decisions on managing their farms and increasing their crop yields. These organizations primarily use data on agriculture and the environment, as well as geospatial data.[211,212] In the same way as these organizations are using big data, it could also be helpful for governments. In the agriculture sector, data on soils and detailed weather data can be used to provide advice on fertilizer applications, pest management and weather predictions. Hence, big data can provide insights that lead to better decisions, help optimize performance, and drive competitive advantage. Big data on nutrition and health status of the population could further help to get a better and quicker picture of problems, raise awareness and money, and support interventions. While big data offers great opportunities, governments need to establish ways to analyze the datasets accurately and in a timely way in order to use them efficiently.

Big data can provide insights that lead to better decisions, help optimize performance, and drive competitive advantage.

To create a truly enabling digitalization environment that benefits all agriculture value chain actors in rural areas, governments need to ensure that smallholders farmers and farmer organizations are included and given a voice to benefit from the opportunities that an enhanced use of digital technologies can bring to the sector. There is an urgent need for data-driven applications and systems that are smallholder-ready. Issues and challenges around ownership, control and exclusion must not be ignored in the rollout of the latest technologies and apps. Making data-driven agriculture smallholder-friendly will help to ensure that it really benefits agriculture value chain actors. Groups representing smallholders and producers must also explore if and how they can become key value-adding intermediaries in the various agri-food systems, acting as smart data aggregators and analysts with data importers and exporters.

Africa has leapfrogged on the use of mobile technology and now has the opportunity to leapfrog in the use of other digital technologies and services for agriculture and for the benefit of smallholder farmers. Important lessons can be learned from some African countries that are at the forefront of progress in harnessing digital solutions along the agriculture value chain.

6. Methodology and Country Case Studies

Several countries across Africa demonstrate a relatively high degree of digitalization in their economies, including in the agriculture sector. Their experience in terms of policy and institutional innovation and interventions on the ground provide important lessons for other African countries seeking to develop and strengthen the use of digital tools and services for an agricultural transformation.

The indicators for country selection

To select countries for this analysis, the report assumed that a well-established regulatory environment is indispensable for the development and beneficial use of digital technologies in agriculture and food systems. Therefore, in the first step, the World Bank's 2017 Enabling the Business of Agriculture (EBA) ICT Index[213] was chosen as an indicator in order to identify the best performing countries based on their regulatory frameworks. The EBA ICT Index measures laws, regulations and policies that promote an enabling environment for the provision and use of ICT services, particularly in rural areas.[iii] The EBA ICT index is likely to capture government efforts in creating an enabling environment for agricultural digitalization, considering that most actors in the agriculture value chain continue to be based in Africa's rural areas.

In the second step, the selection considered countries' levels in ICT services and content in wide use, assuming that actual usage of mobile technologies helps to increase the number and quality of services, also in the agriculture sector. Hence, the 2017 Mobile Connectivity Index (MCI) of the Global System for Mobile Communications (GSMA)[214] was chosen as another indicator, reflecting countries' ability to adopt and use mobile internet, including different dimensions of enablers such as infrastructure, affordability, consumer readiness, content, use and services. These enablers are further defined by a subset of indicators, referred to as dimensions. A classification with focus on mobile internet is considered as important especially regarding low- and middle-income countries.[iv,v]

While the report does not claim a causal relationship between the two indices, a study by the World Bank displays a high and significant correlation (r = 0.70) between both indices, indicating a strong relevance of the regulatory framework for the actual use of technologies.[215] Therefore, combining the two indices allows for selecting countries where efforts to create an enabling environment effectively increase the digitalization uptake.

Clustering countries based on their performance

The ranking of countries based on their scores in both indices resulted in four clusters (see Figure 1). The clusters were organized according to countries' high or low score in the respective index. The threshold for the EBA ICT index was chosen based on an analysis comparing the scored performance with their performance against a global ideal or "distance to frontier."

Countries with an EBA ICT index equal to or higher than 4.5 were identified as "developing" and "prospering" in their regulatory framework performance and therefore considered as high performers in our clusters.[216] The threshold for low and high performance for the MCI is based on GSMA's own classification. The index classifies countries into low, medium and high performers with respect to their strength to adopt and use mobile internet. Since all African countries considered in this analysis are classified as medium performers, we differentiate between medium performers (MCI 41–60) and low performers (MCI 0–40) but define the medium performers as high performers for the purpose of our clusters.

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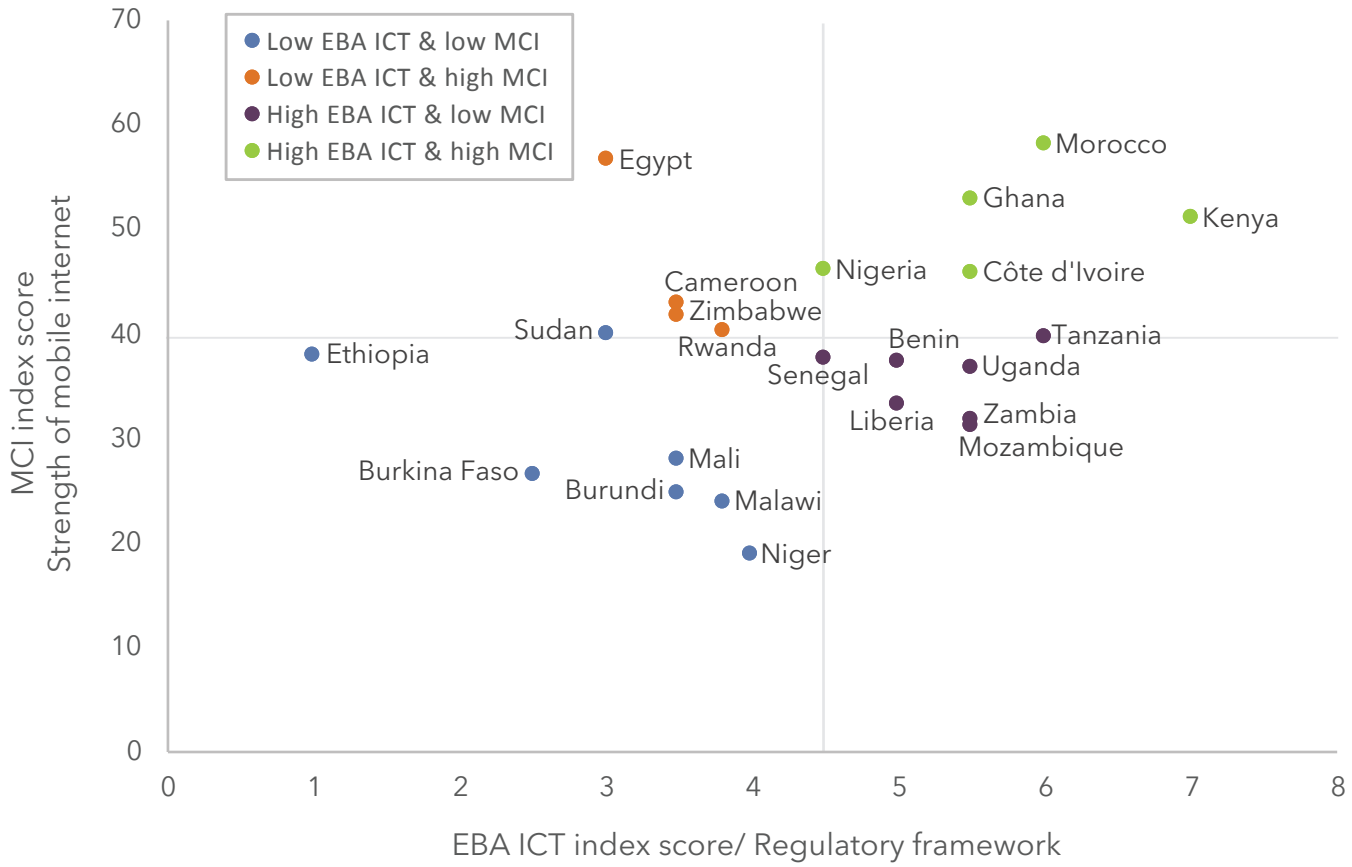
iii The EBA ICT indicator measures laws, regulations and policies that promote an enabling environment for the provision and use of ICT services, particularly in rural areas. EBA 2017 presents data for 62 countries, including 23 African countries. Two overarching themes—gender and environmental sustainability—are also included in the report's analysis to ensure that the messages developed by EBA encourage inclusive and sustainable practices. The index ranges from 0–9 (9 indicating high performance) (World Bank 2019).

iv The enabler 'infrastructure' is defined by network coverage, the spectrum of network, the network performance and other enabling infrastructure including electricity and the number of servers. The dimension of 'affordability' is built through of the assessment of inequality, mobile tariffs, taxation, and handset prices. Furthermore, the enablers 'consumer' and 'content' refer to gender equality and basic skills, and local relevance and availability.

v The GSMA Mobile Connectivity Index is an analytical tool that measures the performance of 163 countries (44 African countries), representing 99% of the World's population, against the four key enablers of mobile internet adoption – infrastructure, affordability, consumer readiness, and content and services. Scores for each of these four key enablers are combined to produce a single composite measure for a given country of the strength of the foundations to support widespread adoption of the mobile internet. The index ranges from 0-100 (100 indicating a high country strength to support the adoption of mobile internet) (GSMA 2019).

FIGURE 2 Clustering of countries according to their EBA ICT and MCI index scores



Source: Authors' compilation based on data from the World Bank (2019) and GSMA (2019).

Based on the different clusters, Côte d'Ivoire, Ghana, Kenya, Morocco and Nigeria are chosen from the high-performing countries under EBA ICT *and* high-performing under MCI cluster and will be analyzed in the country case studies (see Table 1).

To strengthen the analysis, two additional countries, Rwanda and Senegal, were chosen from the other clusters—low EBA ICT and high MCI, and high EBA ICT and low MCI, respectively. Both countries have been seeing a rapidly growing interest from investors in supporting African tech start-ups and also were repeatedly recognized as *innovation achievers* between 2012 and 2017 on the Global Innovation Index (GII).[vi,217] Furthermore, initiatives by the governments, such as Rwanda's Kigali Innovation City, aim to address the issues of limited capacity in hardware and software engineering, network design, and large-scale ICT project management in Africa. Lessons drawn from Senegal and Rwanda may complement those drawn from Côte d'Ivoire, Ghana, Kenya, Morocco and Nigeria.

TABLE 1 Regulatory framework performance versus strength to adopt mobile internet[1]

Country	EBA ICT[2]	MCI[3]	Cluster
Côte d'Ivoire	5.5	45.7	High EBA ICT & high MCI
Ghana	5.5	52.7	High EBA ICT & high MCI
Kenya	7.0	51.0	High EBA ICT & high MCI
Morocco	6.0	58.0	High EBA ICT & high MCI
Nigeria	4.5	45.9	High EBA ICT & high MCI
Rwanda	3.8	41.7	Low EBA ICT & high MCI
Senegal	4.5	37.3	High EBA ICT & low MCI

[1]Since the data for the EBA ICT Index is limited to 23 countries, we only consider these in our cluster.

[2]The threshold for high EBA ICT performance is ≥4.5.

[3]The threshold for high MCI performance is >40.

vi The GII evaluates the performance of 126 countries on their institutions, human capital and research, infrastructure, market sophistication, and business sophistication – all of which contribute to a healthy environment for innovation to happen.

CASE STUDY

Côte d'Ivoire

The Government of Côte d'Ivoire has been ambitious in developing policies and regulations to promote greater ICT penetration and the provision of ICT services to different sectors of the economy, including the agriculture sector. The country's EBA ICT score[vii] of 5.5 out of 9 indicates a strong enabling digital environment with regard to laws, regulations and policies, while its score of 45.7 in the GSMA Mobile Connectivity Index (MCI)[viii] highlights wide adoption and use of mobile internet. Compared to other African countries, stakeholders in the agriculture sector are in a position to seize the opportunities presented by ICTs to improve outcomes at all stages of the agricultural value chain. This achievement is largely due to the government's commitment at institutional and programmatic levels to create an enabling environment for agricultural digitalization.

Institutional innovation

Five institutions lead on the uptake and expansion of digital services within the different sectors of the economy. The Ministry of Communication and Digital Economy and Post (MICENUP) oversees the development and promotion of ICTs and the creation of a conducive business environment.[218] MICENUP has undertaken several legislative reforms, including an update of the telecommunication legislation dating back to 1995. The legislation was aligned with the regional recommendations of the West African Economic and Monetary Union in 2012 and covered major areas such as licenses and authorizations, identification of relevant markets and market power, and consumer protection.

The National Society of Computer Development (SNDI), a state-owned company operating since 1999 under the supervision of the Prime Minister's office, oversees the Information Technology and Information System projects run by the government. In 2006, the government approved and supported the creation of a free zone dedicated to the development of biotechnology and ICT in the city of Grand Bassam. Village des Technologies de l'Information et de la Biotechnolgie de Côte d'Ivoire (VITIB SA), a public limited company created in cooperation with national and international partners, oversees the management, operation and promotion of biotechnology, information and communication technologies in the free zone. Companies in the free zone enjoy significant advantages, including zero percent customs duty for the first five years and 1 percent from year six, with the possibility of a tax rebate, exoneration from value added taxes (VAT), and no limit on foreign and local investments.[219]

Furthermore, in 2012, the government established the Ivorian Agency for Radio Frequency Management (AIGF), which focuses on radio frequency management, important for the dissemination of information.[220] The Universal Service National Agency (ANSUT), also created in 2012, ensures universal access to ICTs and drives digital development, making Côte d'Ivoire a model for ICT usage and contributing to the development of the eAdministration (the use of ICTs in public services). To achieve universal access to ICTs, ANSUT seeks to make ICT available and accessible to all, strengthen ICT skills and literacy, promote the development of local content, and build a powerful and secure digital economy.[221]

Finally, the Telecommunications Regulatory Authority of Côte d'Ivoire (ARTCI) was created in 2013 as a public institution with legal status and fiscal autonomy. ARTCI is responsible for enforcing the laws and regulations governing the telecommunications and ICT sector, including monitoring obligations of operators and service providers; protecting consumer, operator and service provider interests; and creating an environment conducive to the sustainable development and diffusion of ICTs.[222,223] Furthermore, several laws have been passed to create an enabling environment for ICT uptake. For instance, in 2015 the government exonerated the ICT sector from VAT and reduced custom duties for ICT and electronic equipment through 2018.[224]

In addition, the government has started to equip public agencies in charge of agricultural development with ICTs for high quality and timely service provision. The National Agency for Support to Rural Development (ANADER), created in 1993, is responsible for improving the living conditions for people in rural areas through the professionalization of farmers and agricultural organizations.

vii The EBA ICT indicator measures laws, regulations and policies that promote an enabling environment for the provision and use of ICT services, particularly in rural areas. The index ranges from 0-9 (9 indicating high performance). An index equal or higher than 4.5 is identified as 'developing' and 'prospering' in the regulatory framework performance and therefore considered as high performers in our cluster

viii The GSMA Mobile Connectivity Index measures the performance of 163 countries (44 African countries), against the four key enablers of mobile internet adoption – infrastructure, affordability, consumer readiness and content and services. The index ranges from 0-100 with 100 indicating high national capacity to support the adoption of mobile internet.

ANADER designs and implements appropriate tools and approaches and adapts programs to ensure the sustainable growth and development of the agriculture sector. To reach as many farmers as possible, even in the most remote areas, ANADER created the e-extension system for electronic agricultural extension services in 2017, which serves as an interactive response voice-server and call center through which farmers can pose technical questions and seek advice on farming practices.[225]

Policy and programmatic innovation

The first mobile license was introduced in 1996 after the liberalization of the telecommunications sector in 1995. Since the 2000s, the ICT sector in Côte d'Ivoire has experienced a real uptake with the Plan for the Development of the National Infrastructure of Information and Communication 2000–2005. Under this plan, the government promoted the use of ICTs and set out plans to develop the necessary infrastructure for their adoption, including in the most remote areas. Using ICTs, both policymakers and farmers received information on best practices for agriculture and natural resources management.[226] Between 1997 and 2005, the number of mobile-phone services subscribers increased from 178,349 to 2,607,954.[227] Over the next ten years, 2005–2015, the share of mobile services subscribers in the population increased from 11 percent to 53 percent. Moreover, through increased collaboration between the private and public sector, the uptake of digital financial services has risen sharply, to almost 10 million mobile money accounts in 2015.[228]

Recognizing the importance of ICTs in achieving widespread connectivity to global markets and networks, the government developed a comprehensive national e-agriculture strategy in 2012 and updated it in 2014.[229] The e-agriculture strategy was designed jointly by the Ministry of Agriculture and MICENUP. It aims to modernize the country's agriculture sector and to enhance its productivity, specifically with an increase in exports of cocoa, coffee and other crops, while reducing food imports. The strategy sets out plans to build an ICT infrastructure for the agriculture sector and develop a legal and institutional framework for the adoption of ICTs to facilitate the use of comprehensive, real-time, multipurpose agricultural information services. The strategy also aims to ensure that farmers, people living and working in rural areas, and government officials working in the agriculture sector have adequate access to the information services and receive training to improve their digital literacy.[230]

In its pursuit of increasing the uptake of digitalization, the government initiated the One Citizen, One Computer,

Côte d'Ivoire

One Internet Connection program in 2015 through MICENUP and implemented by ANSUT. The program aims to improve the access to high-quality ICT services for more than 500,000 households by 2020. It was implemented under a public-private partnership involving the country's mobile operators and can be accessed by everyone, including those working in the agriculture sector. Under the program, a computer costs around US$110, compared to US$330 to $440 when bought at a shop.[231,232]

Between 2013 and 2016, the Côte d'Ivoire Coast Coffee-Cocoa Council and ANADER, with the support of World Education Inc., implemented the CocoaLink program, which uses voice messages and SMS to deliver agricultural and other useful practical information to cocoa farmers in remote areas. It offers advice on good farming practices, farm safety, laws on child labor, health, pest and disease prevention, postharvest handling, and crop marketing. Through CocoaLink, famers even in the most remote farming communities with limited agricultural extension services received and shared information. The use of ICTs has also improved the monitoring and evaluation system of the program. Data collected allowed partners to evaluate the project's performance based on selected indicators and to make improvements where needed. CocoaLink was expected to reach more than 100,000 cocoa farmers by 2016.[233]

A web-based software has also been used to improve the postharvest handling of cocoa to improve quality preservation. In 2012–2013, as part of the implementation of the reform of the coffee-cocoa sector, the Directorate of Technical Operations of the Côte d'Ivoire Coffee-Cocoa Council introduced a new ICT-based input management system to guarantee the efficiency and transparency of government support to producers. The Information and Control System for the Distribution Operations of Phytosanitary Products, Seeds and Bagging (SICOPS) was developed to improve the process of packaging and bagging, ensure the traceability and improve the provision of storage bags to farmers, significantly lowering postharvest losses across the country. SICOPS was progressively adapted to the distribution and management of other inputs, including improved seeds and phytosanitary products.[234]

In addition, since 2012, the government has been implementing a stabilization mechanism for the sale of coffee and cocoa using a web platform. The objective is to optimize international sales, to ensure that the benefits accrue to smallholders, rather than being captured by intermediaries. To do this, a system for email auctions, the Integrated System of Sales by Auctions of Coffee and Cocoa, was set up. Sellers and buyers can negotiate and agree on sales prices through the platform. Farmers now sell most of their coffee and cocoa through these electronic auctions and the government uses the average selling price to set a minimum sale price. In 2016, 70 to 80 percent of Côte d'Ivoire's anticipated harvest of cocoa was sold through an electronic auction system.[235,236]

Côte d'Ivoire's strong enabling digital environment has allowed the private sector to take an active role in the digitalization of the agriculture sector. Few cocoa farmers have a savings system. As a result, they are not able to deal with unexpected events or build a credit score to borrow from banks. While few cocoa farmers have a bank account, over half now have access to a mobile money account. Through a partnership with the microfinance institution Advans Côte d'Ivoire and the mobile operator MTN, farmers can now access a digital savings account using their mobile phones. In 2016, more than 7,000 cocoa farmers from 58 cooperatives had subscribed to the service and were able to open a savings account with a formal financial institution.[237] Furthermore, since 2014, Orange Côte d'Ivoire has been operating m-Agri, a platform providing farmers with information on product prices, cultivation techniques and national and international price trends.[238] More recently, Palmafrique developed a digital technology application for the geolocation of plants or the payment of bonuses and salaries for staff in remote areas.[239]

The Government of Côte d'Ivoire has shown a strong commitment to increasing the uptake of digitalization in the economy through institutional and programmatic innovations. The government has recognized the importance of access to ICTs and the creation of a conducive business environment to sustainably increase ICT-based services relevant for the development of efficient food value chains. However, more specific institutional and programmatic innovations targeting the agriculture sector are required to fully benefit smallholder farmers and the food systems within which they operate. Furthermore, public-private partnerships need to be actively facilitated and promoted to scale up interventions that have been shown to be effective, for instance, in the coffee and cocoa sector. ■

CASE STUDY

Ghana

Ghana has a rapidly developing digitalization environment. According to the World Bank's EBA ICT Index, Ghana ranks among the top five best performing African countries.[ix] The EBA ICT index score of 5.5[x] out of 9 indicates a strong enabling digital environment with regards to laws, regulations and policies.[240] Secondly, according to GSMA's MCI[xi], Ghana's mobile internet adoption rate and usage increased by 15 percent within the last four years, with an MCI score of 52.7 in 2017.[xii] The country is performing particularly well in 3G network coverage and in providing the first 4G services, affordable handset prices, gender equality in terms of the labor market, and a higher ratio of bank accounts held by women, as well as content availability in terms of mobile services in local languages.[241]

Institutional innovation

At the institutional level, the Ministry of Communication (MoC) plays a critical role in developing an enabling digital environment and a framework to support the digitalization of the economy. The MoC was established out of the Ministry of Transport and Communications in 1993 to promote Ghana's rapid development into a knowledge-based society and a smart economy. It further aims to strengthen the institutional and regulatory framework for managing the ICT subsector, enhance the adoption of ICTs, including in the agriculture sector, and facilitate the provision of quality meteorological data and forecasts in support of weather-sensitive sectors. Under the MoC, eight agencies and statutory bodies work to formulate policies leading to the cost-effective creation of ICT infrastructure and services in order to promote economic competitiveness across all sectors.[242]

Moreover, the National Information Technology Agency (NITA) was established by Act 771 in 2008 as the ICT policy implementing arm of the MoC. NITA is responsible for developing and promoting new, innovative technologies, ensuring the growth of ICT through continued research and development in partnership with the private sector, planning and technology acquisition strategies, and assisting the government to generate growth and employment by leveraging ICT and public-private partnerships.[243]

ICT infrastructure in Ghana is further overseen by the National Communications Authority (NCA). The 1996 National Communications Authority Act and the 2008 Electronic Communications and Transactions Act were passed to strengthen the capacity of the Authority. The NCA grants licenses, ensures fair competition, establishes and monitors quality of service indicators, educates and protects consumers, authorizes type approval and equipment standards, and coordinates international radio frequency.[244]

Although the Ministry of Food and Agriculture (MoFA) is not the primary driver in the digital transformation process, some of its units, including the Statistics, Research and Information Directorate (SRID) advocate for the use of modern technologies and ICTs in the agriculture sector. SRID provides relevant, accurate and timely agricultural statistics such as the annual market surveys to provide information on commodity prices and information for stakeholders. These are increasingly based on big data and captured by digital technologies, including tablets and mobile phone apps.[245] MoFA's ICT Unit emphasizes the use of ICTs in agriculture[246] and has adopted five principal elements and objectives to stress the ministry's strategic approach to the e-Agriculture model:

- ICT policy: Promote a pro-competition policy and regulatory reforms to encourage the uptake of ICTs by stakeholders in the agriculture sector. Facilitate the establishment of public-private partnerships to collate and disseminate agricultural information domestically and internationally. Create awareness on the e-Agriculture platform through TV, radio, newspapers and social media.
- ICT access: Foster access to ICT and dissemination of information for underserved populations, particularly the poor in both rural and urban settings, ethnic minorities, youth and women. Develop and maintain a

ix Overall, Ghana ranks 22nd out of 62 included countries in the EBA.

x The EBA ICT indicator measures laws, regulations and policies that promote an enabling environment for the provision and use of ICT services, particularly in rural areas. The index ranges from 0-9 (9 indicating high performance). An index equal or higher than 4.5 is identified as 'developing' and 'prospering' in the regulatory framework performance and therefore considered as high performers in our cluster.

xi The GSMA Mobile Connectivity Index measures the performance of 163 countries (44 African countries), against the four key enablers of mobile internet adoption – infrastructure, affordability, consumer readiness and content and services. The index ranges from 0-100 with 100 indicating high national capacity to support the adoption of mobile internet.

xii Ghana's MCI increased from 45.8 in 2014 to 52.7 in 2017.

National Agricultural Database of farmers and agricultural and other information.

- ICT capacity: Develop the capacity of directorates, projects, institutions, units and individuals to respond to ICT agriculture workforce demands. This also includes the creation of staff-stakeholder-centered learning environments, MoFA Information Centers, multi-use telecenters and piloting emerging alternate technologies that foster inexpensive, low-power alternatives to PCs.
- ICT applications: Demonstrate innovative ICT applications in local languages and with cross-sectoral objectives including: agriculture, conflict management, democracy and governance, economic growth and trade, education, energy, environment, health, humanitarian assistance, natural resources management, poverty reduction, urban programs, and women in development. Develop or acquire applications to collect, collate, store, archive and share information.

In addition to government ministries like the MoC and the NCA, the ICT sector in Ghana consists of various private partners including telecommunications operators, internet service providers, VSAT data operators, software developers, broadcast institutions, ICT education providers, and others. Also, a number of private companies and some start-ups have begun to offer (smart) phone apps and services with features relevant to the agriculture sector.

Policy and programmatic innovation

In 2003, Ghana devised a roadmap for the development of its information society and economy through the Ghana ICT for Accelerated Development Policy (ICT4AD). The policy seeks to engineer an ICT-led socio-economic development process with the potential to transform Ghana into a middle-income, information-rich, knowledge-based and technology-driven economy and society. On agriculture, ICT4AD modernized the sector through the use of ICTs to improve on the sector's efficiency and productivity and to develop an agribusiness industry. In addition, ICT4D aimed to promote basic as well as cutting-edge agriculture-based R&D to improve the yields, agricultural processes and productivity of some of the country's main crops including cashews and cacao; and to support the development of marketable value-added agricultural products capable of competing on the domestic, regional and global market. In detail, the strategy encouraged market research through the use of ICTs. It also endorsed the development of Geographical Information Systems (GIS) applications to monitor and support sustainable environment use, and food insecurity and vulnerability information and mapping systems. In addition, the strategy aimed to revitalize agriculture extension services by empowering and equipping farm extension service workers with relevant ICT skills, to establish an agriculture information system, to utilize ICTs to link farmers and farmer groups to resources and services, and to reduce preharvest and postharvest losses in agricultural production through the development and adaptation of improved technologies.[247]

The ICT4AD is currently in its fifth phase (2019–2022) with a focus on the production, development and delivery of ICT products and services with less emphasis on ICT deployment and exploitation, which had been the focus of earlier phases.[248]

The importance of ICT development was further embedded in Ghana's second National Agricultural Investment

Plan (NAIP), the Medium Term Agriculture Sector Investment Plan II (METASIP II) covering the period 2014–2017. The investment plan emphasized accelerated agricultural modernization and sustainable natural resource management in order to transform the agriculture sector and to increase productivity, output and incomes, create jobs, and ensure food security. Greater involvement of the private sector was envisioned, as well as increased investment and management of the sector as a whole. To facilitate access to input, research, technology and product markets, the NAIP outlined various links to be established between smallholders and agribusinesses. The plan specifically advocated for the use of mass extension methods such as radio, TV, and communication vans for knowledge dissemination. In addition, the institutional coordination for agricultural development was improved through District Agricultural Advisory Services using ICT and other digital technologies, providing advice on productivity enhancing technologies. E-governance platforms that disseminate information and engage the public sector were optimized to increase investments and to accelerate the creation of jobs in agriculture. Furthermore, the use of ICTs, especially mobile phones and media to disseminate market information and the use of early warning meteorological information from the Meteorological Service Agency were promoted.[249]

In 2017, the MoFA released an ambitious policy framework, Planting forFood and Jobs (PFJ) 2017–2020, committed to increasing agricultural productivity and catalyzing structural transformation through increased farm incomes and job creation. Part of the framework is the use of e-Agriculture platforms, which are implemented in collaboration with the ICT Unit of the Ministry. The main objective of the e-Agriculture platforms is to provide affordable, prompt and efficient agricultural services, which are delivered through the use of the internet and other ICT services.[250] The e-Agriculture program, which was already implemented in 2011, includes components such as the e-Farm information, a service accessible via free calls that informs on best farm practices for cassava, yam, cocoyam, rice and maize, in local languages. Other components include the Call Centers, a phone service that links farmers with specialist support, e-Learning and Resource Centers, a web portal, and e-Field extension services. The e-Field-extension aims to collect farm and farmer's data through use of digital technologies by agriculture extension officers. Besides the mapping of farmlands, collection of biometric data and disease and pest monitoring is established in order to boost accurate and prompt response to field needs and support an early control system to safeguard food security. While the e-Agriculture platform helps farmers source and market their outputs, the success of the PFJ strategy itself, including the provision and collection of accurate data and information, and the timely payment of subsidies to farmers in remote areas will heavily rely on the extent to which mobile technologies are being deployed and used among smallholders.[251,252]

To complement the outlined policies and strategies to expand and improve the ICT infrastructure and availability of e-services, the government passed the Data Protection Act, 2012 (Act 843), safeguarding personal information and data privacy. A Data Protection Commission was established as an independent statutory body to ensure and enforce compliance with the Act.[253]

Through the MoC, paperless port operations, an integrated e-immigration, e-procurement, e-parliament, e-justice and e-cabinet system as well as smart workplaces were initiated and represent a significant milestone in Ghana's journey to creating an enabling digital environment. In addition, the National Digital Property Addressing System (NDPAS), launched in 2017, aimed to provide every property in Ghana with a unique digital address.[254] Under the framework of the World Summit on Information Society, 69 Regional Community Information Centres have been built in nine different regions in Ghana.[255] Their objective is to bring government e-services including passport services and birth registrations to rural areas, and to disseminate information on health, local government, environment, and agriculture.[256]

In 2018, with support from the World Bank and the Rockefeller Foundation, the government opened the Accra Digital Centre to attract and retain ICT and information technology enabled services companies, promote entrepreneurship and job creation, foster digital innovation through ICT R&D programs, and provide technology solutions to various sectors of the economy through partnerships with private sector firms, existing innovation spaces, academic institutions, investors, and other stakeholders. The center provides a Mobile Applications Laboratory (mLab) and an Innovation Hub (iHub). The former is designed to host offices, different testing labs for robotics, AI and other emerging ICT areas. The iHub is a co-working space, suited for start-ups and entrepreneurs, with a large event space for hosting events. [257,258]

The MoC also leads on different ICT initiatives. In addition to a digital terrestrial TV program and enhancing the broadband capacity in the country, there are two flagship programs. Through the e-Transform project, which is jointly led by the MoC and the World Bank, the government aimed to establish unique electronic identification systems and enable access to public services while promoting better admission to online transactions and financial services. Through the innovative applications, the focus was to improve service delivery in the priority areas of health, education, agriculture, judicial, and parliamentary services. Furthermore, in 2008, the government initiated the Eastern Corridor Fiber Optic Backbone program, investing approximately US$43 million in the development of a solid and dependable ICT infrastructure. The project was implemented by the MoC as part of the ICT infrastructure development with the vendor Alcatel-Lucent Denmark, which aimed to bridge the digital divide between rural and urban communities.[259]

While some of the start-ups and technologies focus on providing one specific service to farmers, there are some that offer overall farm management support. Ghanaian start-up Esoko offers such data services in Ghana and other African countries. Through the Esoko data collection tool, farmers can monitor and analyze their farm records. The service, which can be accessed via a smartphone app or website, can link farmers to advisory services, markets and market prices, and financial services. Farmers are able to make payments directly via the Esoko smart-card system and can subscribe to the Esoko service for US$1 per month.[260] While Esoko targets farmers in order to provide digital services, the data that is captured through the digital platform is also being used as a source of big data by the MoFA. Through one of Esoko's services, Insyt, 34,000 farmers have been profiled by the MoFA.[261]

The start-up Trotro Tractor has been operating in Ghana since 2016, providing a mobile hiring service for agricultural tools and equipment, including tractors and machines. Since most farmers who need ploughing services are unable to reach out to mechanization centers, tractor services or operators, the service offers an option especially for smallholder farmers to request a tractor service through text messages or the online platform. Through the platform, smallholder farmers are then able to schedule and prepay for services. In addition to the benefits for the farmer, the tractor owners are able to monitor movement and work progress of their equipment.[262] Recently, Trotro Tractor has been awarded for one of the five best AgriTech Solutions by AppsAfrica Innovation Awards 2018.[263]

Other providers offer services related to trade, marketing, mobile banking, and insurance. AgroCenta, founded in 2015, has established three platforms: AgroPay, AgroTrade and AgroMart. AgroPay enables farmers' access to digital services such as mobile money payments, micro-lending, input financing and crop insurance, while AgroTrade links farmers with large buyers and ensures direct trading. With AgroMart, everyone can get involved as a distributor, helping smallholder farmers to sell their produce at fair market prices. Currently, over 30,000 farmers are registered to one of the AgroCenta services.[264]

In addition to African companies and start-ups, international companies are also established in Ghana. In 2010, Ignitia, a Swedish company, started their work in Ghana. The company developed a tropical forecast model with an accuracy of 84 percent, predicting weather down to a specificity of 3 km x 3 km. Each morning the subscribers receive a 48-hour rain forecast via SMS in their local language, specific to their location. The service costs only a few US cents per day, and as the technology is easy to use, the service is accessible for most smallholder farmers in rural areas. In 2017, Ignitia had 330,000 subscribers in Ghana alone and has since expanded its services to Nigeria and Mali.[265]

Ghana has been performing well in devising an enabling environment for the use of digital technologies across sectors. The country's institutional and policy commitments are significant, establishing the MoC and setting up the ICT4AD Policy. Particularly through increasing private sector involvement, Ghana has achieved a remarkable mobile internet coverage of 3G and 4G networks and has been able to address gender inequality with respect to the use of mobile and internet services. Although Ghana has been one of the first African countries with laws to protect personal information, serious measures to address cybercrime and to establish online child protection are urgently needed.[266] ■

CASE STUDY

Kenya

Kenya has an advanced digital environment. According to the World Bank's EBA ICT, Kenya ranks top among African countries on the index. With a score of 7.0 out of 9, Kenya offers a superior system of laws, regulations and policies that promote an enabling environment for the provision and use of ICT services, particularly in rural areas.[xiii] In addition, according to GSMA's MCI, Kenya performs particularly well on the price of handsets, gender equality and network coverage (85 percent of the population has access to 3G coverage). However, owing to weaker network performance, that is, upload and download speeds, Kenya's performance on the MCI scores an average 51.[xiv] Even so, Kenya has the second fastest internet in Africa according to the Worldwide Broadband Speed League (after Madagascar).[267] Nevertheless, as part of its long-term development plan, the government aims to roll out 4G networks across the country to provide faster internet and increase bandwidth capacity.[268] To date, strong institutional, policy and programmatic developments ensure that Kenya sustains its leadership on digitalization in agriculture across the continent.

Institutional innovation

Kenya's Vision 2030 offers a blueprint for its long-term development pathway, implemented in five-year medium-term plans (MTPs). The prevalence of ICT within its three pillars (Economic and Macro, Social, and Political) and nine foundations for the pillars provides an insight into the importance of digitalization in achieving Kenya's ambition to become "a newly-industrializing, middle income country providing a high quality of life to all its citizens in a clean and secure environment."[269] Specifically, the information, communications and technology; environment, water and sanitation; and science technology and innovation pillars of Vision 2030 have a bearing on digitalization for agriculture and food security.

The Information and Communication Technology Foundation pillar of Vision 2030 aims to upgrade ICT capacity, and improve public service delivery using ICT, including support for food security through the development of a digital land management system, GIS, mapping of farm productivity, forecasting, digital meteorological systems, market information systems, e-farming, farm produce management systems, agricultural information systems, remote sensing, population management systems, and health and nutrition information systems.[270]

The Environment, Water and Sanitation sector within the Social Pillar emphasized the modernization of meteorological services in five thematic areas: observation network, data exchange network, data processing, analysis and forecasting systems, weather products dissemination and research for development.[271] By 2018, 88 Automatic Weather Stations (AWS), automatic hydrometeorological stations, upper air observing systems in Garissa and Lodwar, and automatic airport weather observing systems had been installed.[272]

Finally, the Science, Technology and Innovation Foundation Pillar has led to the development of the Kenya National Innovation Agency (KENIA). Set up as a state corporation under the 2013 Science, Technology and Innovation (STI) Act, No. 28, by the Ministry of Education, KENIA is responsible for leveraging, co-ordination, promotion and regulation of innovation and entrepreneurship, thus institutionalizing linkages between universities, research institutions, the private sector, and the government. KENIA has already supported the development and commercialization of the Ujuzi Kilimo soil kit—an innovative sensor technology connected to a database for analysis of farm data, which enables the farmer to make informed decisions for targeted interventions.[273]

While the Vision 2030 sets out a longer-term ambition for the country, the current administration has included the target of "100 percent food and nutrition security" by 2022 within its own mandate. The government has set out goals to increase the average daily income of farmers, reduce the cost of food as a share of income, create 1,000 jobs in agro-processing, and reduce the number of food insecure people. The government considers innovation and technology a key enabler for delivering on this ambition, via the digitization of land titles and expansion of an

xiii The EBA ICT indicator measures laws, regulations and policies that promote an enabling environment for the provision and use of ICT services, particularly in rural areas. The index ranges from 0-9 (9 indicating high performance). An index equal or higher than 4.5 is identified as 'developing' and 'prospering' in the regulatory framework performance and therefore considered as high performers in our cluster.

xiv The GSMA Mobile Connectivity Index measures the performance of 163 countries (44 African countries), against the four key enablers of mobile internet adoption – infrastructure, affordability, consumer readiness and content and services. The index ranges from 0-100 with 100 indicating high national capacity to support the adoption of mobile internet.

e-government services system, expansion of the national fiber optic infrastructure and establishment of national science technology and innovation parks.[274]

With the government implementing ICT programs across all its operations and services, it is providing a clear stimulus to drive digitalization across the country. The key ministries involved in the implementation of digitalization in agriculture, also with impetus from Vision 2030, are the Ministry of Information, Communications and Technology (ICT); the Ministry of Agriculture, Livestock, Fisheries and Irrigation; and the Ministry of Land, Housing and Urban Development.

The Ministry of ICT is leading infrastructure development for the ICT sector, including the migration from analogue to digital broadcasting. Within the Ministry, the State Department of ICT and Innovation is responsible for, among other things, National ICT Policy and innovation, promotion of the software development industry, policy on automation of e-government services (including the roll-out of e-agriculture services), development of national communication capacity and infrastructure (including setting up of County ICT Incubation Hubs), and management of national fiber optic infrastructure.[275] The aim of e-agriculture is to provide information on soils, crops, and planting as well as data to help farmers make informed decisions and apply methods of precision agriculture and enhance rural development.[276]

The ICT Authority—a state corporation under the Ministry of ICT—is mandated to promote e-government services, including supervision of their design, development and implementation; as well as to promote ICT innovation and enterprise.[277] The ICT Authority also hosts the Kenya Open Data Portal, which makes government datasets accessible for free to the public in easy reusable formats.[278] The Portal currently hosts several farming and agricultural databases such as Proportion of Households Engaged in Crop Farming, Percentage Distribution of Agricultural Parcels, Proportion of Parcels under Irrigation County Estimates 2005/6, and county crop statistics—all of which provide rich new insights and data for service design and delivery.[279]

Following the introduction of Vision 2030 in 2008, the Kenyan government wrote and implemented the Kenya Communications (Amendment) Act 2009, as well as the Kenya Information and Communications regulations. This legislation, combined with an open market for foreign investment in telecommunications (infrastructure), were expected to improve competition widening choices of ICT services.[280] However, given Safaricom's large market share (65.4 percent as of December 2016), the market is not considered highly competitive. Nevertheless, Airtel is disrupting the market by leasing out its own infrastructure to new mobile virtual network operators, which offer less expensive, more flexible consumer plans although at the cost of slower data speeds.[281] At the same time, others in the private sector have been rolling out their own national ICT infrastructure, including in telecommunications, and data infrastructure. This competition has led to a reduction of rates and increased the adoption of mobile phones and internet.[282]

The Communications Commission of Kenya was also reformed in 2013 (and renamed Communications Authority of Kenya, CA) to regulate the communications sector in Kenya.[283] Originally established in 1999 by the Kenya Information and Communications Act 1998, CA is responsible for facilitating the development of the information and communications sectors including cybersecurity, multimedia, telecommunications, and electronic commerce.

The Ministry of Agriculture, Livestock, Fisheries and Irrigation (MoALFI) also plays a significant role in advancing digitalization in agriculture in Kenya. Although there is not a directorate or department for digitalization, the Ministry has created several connected policies to enhance the uptake and implementation of ICTs in agriculture. In addition, while implementing MTP II (2014–2018), the government reformed the National Agricultural Research Systems through the Kenya Agricultural and Livestock Research Act 2013 to create the Kenya Agricultural and Livestock Research Organization (KALRO). KALRO has since been restructured to form a

more dynamic, innovative and responsive organization to promote, streamline, co-ordinate and regulate agricultural research, as well as expedite equitable access to research information, resources and technology.

Policy and programmatic innovation

Kenya's Agricultural Sector Transformation and Growth Strategy 2019–2029 outlines nine key areas of intervention—flagships that will be the focus for transforming the agriculture sector in Kenya with the aim of achieving 100 percent food and nutrition security.[284] Four of the nine flagships are relevant for digitalization in agriculture, seeking to reform the national subsidy system for inputs, the Strategic Food Reserve for high-needs Kenyans, extension work, and research and innovation:

- **Flagship 2:** focuses on digitizing the national subsidy system to register 1.4 million high-needs farming households within the first five years to 2024 to enable them to access inputs using an e-voucher system. Following a three-year verification program by extension agents, US$50 million will be reallocated to enable farmers to purchase a range of inputs from multiple providers, including private sector agro-dealers.
- **Flagship 5:** calls for digitizing stock and cost management systems in the Strategic Food Reserve. In partnership with the Ministry of Finance, this flagship seeks to introduce competitive bidding for storage, thus enabling the private sector to get access to allocations for these reserves.
- **Flagship 7:** seeks to digitize and update the provision of extension services, including by training 3,000 digitally-enabled youth, small and medium enterprises and public-private partnership officers, as well as project coordinators, and Strategic Food Reserve inventory personnel. Rather than leading this program centrally, MoALFI will encourage uptake at county level by providing a training program and supplementary funding for implementation including from national research organizations. By 2024, it is expected that the flagship will raise the ratio of extension worker to farms to 1:600. This flagship aligns with the National Agricultural Sector Extension Policy (NASEP) 2012 which also encourages increased use of ICTs within Agricultural Knowledge Information Systems. To do this, NASEP seeks to ease access and use of information by establishing an integrated and dynamic database for the sector, investing in capacity building in ICT including creating information points in rural areas, and harmonizing the content and quality of extension messages to make them more user-friendly. NASEP also aims to encourage the private sector to set up and operate rural information centers.[285]
- **Flagship 8:** driven by the need for better access to useable and shareable data, as well as raising the investment in research and innovation, this flagship will improve data collection for better analysis and informed decision- and policymaking thus strengthening links between research and activity on the frontline. In this respect, it will digitize existing data held by MoALFI and associated agencies, and feed this into the Kenya Open Data Initiative; use field data for improvised feedback loops, e.g. tracking the performance of the subsidies or recertification of vendors, etc.; and strengthen data laws and set up open data platforms for agriculture. By 2024, it is expected that this flagship will register more than 3.3 million small-scale farmers for more efficient service delivery; and 1,000 farmer service providers will be logged onto digital platforms, which are informed by the latest research and data.[286]

In addition to the Agricultural Sector Transformation and Growth Strategy, Kenya's Youth Agribusiness Strategy (KYAS) 2017–2021 strongly promotes the role of digital technologies to provide new opportunities for youth in agriculture and its value chains. In order to attract more youth into farming and related activities, to drive agricultural innovation, and research and technology development and deployment, KYAS has allocated nearly US$20 million for 2017–2021 to building capacity of youth by creating knowledge and information hubs and resource centers at county-level, as well as related tech-labs and ICT centers and mobile apps. Moreover, to provide access to markets for outputs, KYAS supports the formation, review and integration of structured information platforms and infrastructure.[287]

The above policies and strategies have provided a framework and the impetus to implement transformative and innovative programs in Kenya.

In October 2018, KALRO launched a pilot agricultural observatory platform in partnership with the World Bank. The platform is designed to enhance access to high-resolution geospatial agro-meteorology data to enable better decision-making among farmers. It uses big data, AI,

and machine learning to provide more accurate, timely and reliable weather data.[288] The US$1 million program also includes training for scientists at KALRO on predictive analytics and integration into agriculture.[289] Separately, in May 2018 KALRO launched 14 mobile apps to help lower prices for consumers, and contribute to smart agriculture and a potential increase in yields. The apps provide advice on best practices for the rearing of indigenous chicken and the production of range pasture seed and dryland crops. This helps farmers identify and prevent pests and diseases that affect their crops and facilitate farmers' access to markets.[290] Based on information shared by Lawrence Mose of KALRO, within a year of their creation, the apps are being actively used by 1,600 users.[291]

Kenya's propulsion into digitalization leadership came from the conception of M-Pesa, which has transformed the financial sector in Kenya, and to a large extent, globally. Safaricom pioneered M-Pesa—the mobile money transfer business—in 2007, the establishment of which required collaboration with the Central Bank of Kenya and called for modifications in existing banking systems and regulations. M-Pesa has over 23 million subscribers and 160,000 agents within Kenya, and over 13.4 million subscribers in 10 countries outside Kenya.[292] In 2018, mobile money transactions in Kenya amounted to US$38.5 billion, an increase of 10 percent over the previous year. This equates to nearly half of Kenya's GDP. Since its launch, the application of M-Pesa has also expanded from its use as a cash transfer tool to being used by businesses for purchases of goods and services, as well as processing of instant short-term loans.[293] Importantly, by providing access to finance for those previously "unbankable," including smallholder farmers, M-Pesa has increased the annual use of inputs of agricultural households by US$42, and annual household income of these households by US$224.[294]

A thriving digital sector in Kenya has attracted complementary finance stakeholders, many of which include digitalization in agriculture in their portfolio. In addition to grant funding from conventional multilateral donors such as USAID, DfID, World Bank, Enabel (Belgium), and Rockefeller Foundation, there is a growing number of angel investors such as Acumen Fund, Omidyar Network and the Bill & Melinda Gates Foundation, and competitions such as the Apps4Africa, Google Apps Developer Challenge and the Orange African Social Venture Prize—all of which are seeking to achieve maximum returns and impact for innovations. Finally, accelerators and digital hubs are building a landscape of co-working spaces where entrepreneurs, innovators and people with technical skills can convene.[295,296] In addition, Google Kenya is working in partnership with One Care Fund to train 100,000 Kenyan smallholder farmers in digital skills through a US$1 million grant to digitize their agribusiness operations and tasks.[297]

Several other M-services have arisen from M-Pesa, including M-Farm and M-Kilimo. The M-farm software provides weather and market price information across agricultural stakeholder groups including farmers, suppliers and manufacturers. It also helps farmers to connect with each other. In Kinangop District, farmers using the M-Farm application declared that their crop yields had increased, and the cost of fertilizer dropped from approximately US$40 to about US$25 as a result of better information on inputs, and overall savings quintupled. Importantly, the increase in savings led to a more diverse diet, and better nutrition including more fruits and animal protein.[298]

Digital solutions in Kenya also help to protect the livelihoods of pastoralists and reduce their vulnerability to climate change. The Kenyan government in partnership with the International Livestock Research Institute and the private insurance sector launched the Kenya Livestock Insurance Program (KLIP) in 2015. KLIP uses satellite technology to monitor the state of vegetation and pasture in remote, arid and drought-prone lowlands of Kenya. When the 'greenness' of the vegetation falls beyond a predetermined level, the index-based insurance kicks in to release payouts to pastoralists, also through mobile payments (M-Pesa). The program covers more than 90,000 livestock units and has made payouts of more than US$7 million to 32,000 pastoralists since 2015. An evaluation of the program in 2018 confirmed that this program significantly reduced household food insecurity among those who were signed up to KLIP.[299, 300]

In conclusion, Kenya has a vibrant environment for digitalization in agriculture. Supported by key government-led initiatives, the private sector is leading in innovating and developing solutions designed to address challenges faced by smallholder farmers and pastoralists in the country. However, without a distinct policy and directorate to oversee the development of this sector, benefits and lessons may not always be captured effectively. Nevertheless, having pioneered the M-Pesa, Kenya has built its identity as a digital leader in Africa. ■

CASE STUDY

Morocco

The Government of Morocco has been ambitious in carefully designing policies and regulations that can promote greater ICT penetration and the provision of ICT services to different sectors of the economy, including the agriculture sector. The country's EBA ICT score[xv] of 6 out of 9 indicates a strong enabling digital environment with regards to laws, regulations and policies, while its score of 58 in the GSMA[xvi] MCI highlights its strength to adopt and use mobile internet. This achievement is largely due to the government's commitment at institutional and programmatic levels to creating an enabling environment for digitalizing its economy, including the agriculture sector.

Institutional innovation

Morocco has several institutions that oversee the uptake of digitalization across its economy. The Moroccan Telecommunications Regulatory Agency (ANRT), created in 1997, oversees the granting of telecom licenses, implementing ICT frameworks and developing legislative and regulatory frameworks for ICT development and to increase the affordability and quality of telecommunications services. ANRT also supports skill development and training and promotes research for innovation and the growth of the telecommunications sector.[301] The Ministry of Economy and Finances also contributes to digitalization uptake by leading the preparation of taxation and finance laws as they relate to ICT use.[302] Furthermore, the Ministry of Industry, Investment, Trade and Digital Economy oversees the design and implementation of government policy related to monitoring and promoting the use of ICTs and investment in the ICT sector through the Agency of Digital Development (ADD), housed within the ministry.[303] The ADD empowers public administrations, companies and citizens to use digital tools and services.[304] In addition, Morocco has emphasized equipping public agencies in charge of agricultural development with ICTs to achieve a high-quality and timely service provision. The Regional Offices of Agricultural Development (ORMVA), situated within the Ministry of Agriculture, are responsible for research, project execution and management of hydro-agricultural equipment, management of water resources for agricultural use, and dissemination of new farming technologies. To achieve their mission, the ORMVA have been equipped with computerized tools that enhance their technical capacity to conduct computer-assisted maintenance of irrigation systems and invoicing for water used for irrigation.[305]

xv The EBA ICT indicator measures laws, regulations and policies that promote an enabling environment for the provision and use of ICT services, particularly in rural areas. The index ranges from 0-9 (9 indicating high performance). An index equal or higher than 4.5 is identified as 'developing' and 'prospering' in the regulatory framework performance and therefore considered as high performers in our cluster.

xvi The GSMA Mobile Connectivity Index measures the performance of 163 countries (44 African countries), against the four key enablers of mobile internet adoption – infrastructure, affordability, consumer readiness and content and services. The index ranges from 0-100 with 100 indicating high national capacity to support the adoption of mobile internet.

Since 1998, the government has also implemented several reforms to liberalize and privatize the ICT sector. These reforms greatly benefited the Moroccan economy and significantly increased the number of people with mobile subscriptions. In 2009, Morocco joined the World Trade Organization (WTO) Information Technology Agreement that removed all tariff barriers on ICT products. In addition to reduced equipment costs, the strong presence of telecom operators in ICT retailing has also helped to boost ICT penetration, including mobile phones, by lowering barriers to access.[306]

Policy and programmatic innovation

ICTs have been in use across numerous sectors of the Moroccan economy and earlier than in many other African countries. However, until recently there was no dedicated digitalization strategy for the agriculture sector. The *Note d'Orientation Generale* (NOG) was designed as a roadmap for all the stakeholders in the ICT sector and aims to sustain the growth and use of ICTs to reduce the digital divide, while also ensuring the implication of all stakeholders. For the period 2015–2018, it aimed to expand universal access to broadband and high-speed broadband. To do so, the NOG supported service providers by strengthening the market and promoting the development of models of infrastructure sharing, particularly in less densely populated rural areas. Finally, the NOG leveraged regulation to open some segments of the telecommunication market to competition, especially business services. [307]

In 2016, Morocco implemented the Digital Morocco Plan (PMN) to meet its aspiration of achieving emerging-economy status by 2020. The PMN emphasizes efficient data transport and processing infrastructure for implementing a digital economy. To achieve this, the PMN encourages new investments in broadband and high-speed broadband infrastructure (fixed and mobile) and the completion of the liberalization process in the telecommunication sector. Furthermore, the PMN recognized the importance of strengthening digital literacy for a rapid digital transformation and Morocco's position as a regional digital hub.[308]

Under the *Plan Maroc Vert* (PMV), ICT-based technologies for agricultural advisory services have been developed

to provide extension services to smallholders. In 2014, Morocco put in place Ardna, a training, research, advisory and communication network under pillar II of the PMV, which is dedicated to coherent development of small-scale agriculture. The program was implemented through a partnership between departments of the Ministry of Agriculture and Maritime Fisheries (MAPM) at national and regional level, the Food and Agriculture Organization of the United Nations (FAO), and farmers and women in rural areas. Ardna is a virtual network for providing advice, research and communication guiding the implementation of the PMV. Through the user-friendly platform, farmers can seek advice from researchers and agricultural extension agents on agricultural best practices and farming techniques. The program facilitates knowledge-sharing and creates links and synergies among all actors in the agriculture value chain. It also enhances competitiveness of farmer organizations through improving their skills and knowledge-base.[309,310, 311]

Under a partnership between MAPM and the *Office Chérifien des Phosphates Group* signed in 2007, ICTs were used to develop a tool promoting the smart and sustainable use of fertilizers. Moreover, a project—Soil fertility map of cultivated soils in Morocco—that is part of PMV was implemented by the National Institute of Agronomic Research (INRA) in collaboration with the Hassan II Institute of Agronomy & Veterinary Medicine and the National School of Agriculture of Meknes. The soil fertility map depicting pedological data was created using geographic information systems and is openly accessible on the internet. The project also developed a computer system for improving the capacity of agricultural advisors, extension agents of the MAPM and other actors in soil analysis and crop fertilization management. The soil fertility map covers the entire cultivated area of 8.8 million ha, and ensures that farmers use the right type of fertilizer to meet the needs of for their crops and soil type.[312]

The National Office for Sanitary Safety of Food Products (ONSSA) also developed a new national system for animal identification and traceability (SNIT), implemented in 2015 as part of the PMV. Livestock can be identified using electronic technology loops that communicate with the national SNIT database via mobile phone networks. The system serves as a tool to increase transparency and traceability while promoting Moroccan animal products on international markets such as the European Union. In addition, the identification tags have other benefits for breeders too, including evidence of ownership and theft prevention, facilitating access to government subsidies, and ensuring that meat meets quality and safety standards. After its official launch, a widespread campaign identified approximately 2.9 million cattle to be tagged, equivalent to 99 percent of the national cattle herd.[313]

In addition, to improve the efficiency of the agriculture value chain, the Moroccan government, through the Ministry of Agriculture, set up an information system (ASAAR) in 2011 to provide farmers, traders and consumers with updated information on market prices, allowing them to make more informed decisions on commodity prices, and when to buy or to sell their produce. In addition, the system enables coordination and integration of farmers into the value chain, allowing them to add value to their crops along the value chain. While the ASAAR primarily serves the various stakeholders in the agriculture value chain, it also provides the government with important information on market conditions, with the aim of improving decision-making in the areas of agricultural policy and food security.[314] Moreover, Morocco has deployed two satellites, which enable a range of applications, such as monitoring of agricultural activities, prevention and management of natural disasters, and monitoring of environmental trends and desertification.[315]

Furthermore, Morocco's enabling digital environment and access to the internet has allowed the private sector to take an active role in the digitalization of the agriculture sector. One example is the Moroccan platform for the sale or purchase of new or used agricultural equipment, AgriAffaires.ma, developed in 2017 by the start-up AgriSolutions SARL. The platform connects farmers and sellers of farming and livestock equipment, including secondhand machinery, and agricultural land. The platform allows for quick and easy online posting of announcements.[316]

The government of Morocco has committed to increasing the penetration of ICTs through institutional and programmatic innovations over the past years, which has contributed substantially to an increased digitalization uptake that benefits the whole economy, including the agriculture sector. In addition, the government has recognized the importance of a conducive business environment to sustainably increase ICT-based services relevant for strengthening food value chains. However, public-private partnerships need to be more actively facilitated and promoted for a sustainable agricultural digitalization. ■

CASE STUDY

Nigeria

Digitalization in Nigeria's agriculture sector is advancing rapidly. The government's drive to shift away from oil revenues and toward less-developed sectors is providing a strong stimulus to modernize the agriculture sector. Nigeria's score of 4.5 of 9[xvii] on the World Bank's EBA ICT Index indicates a prospering enabling digitalization environment.[317] With a score of 45.9 in GSMA's MCI[xviii], Nigeria is performing particularly well in providing affordable handsets, reducing mobile-specific taxation, and creating gender equality in the labor market.[318]

Institutional innovation

Nigeria's economic transformation plan covering the period 2009 to 2020 has been integrated in Vision 20:2020. Vision 20:2020 calls for a structural transformation of the Nigerian economy away from its reliance on oil production and a revitalization of other sectors, including agriculture. To deliver double-digit growth, the Vision aims to transform agriculture in several ways, including through the use of ICTs, to encourage more young people and recent graduates to enter the sector. At the same time, Vision 20:2020 endorses ICT as a key strategic objective to drive Nigeria's transition to an industry-based economy, not only to meet domestic needs, but also to exploit international market opportunities. In particular, the Vision promotes the development of local manufacturing, capacity and content to meet the needs of the ICT sector, as well as relevant R&D.[319]

These overarching objectives for economic direction guide Nigeria's Federal Ministry of Communications Technology (FMCT), and Federal Ministry of Agriculture and Rural Development (FMARD), with the former leading on infrastructure and regulatory aspects, while the latter focuses on its application in the agriculture sector. FMCT was established in 2011 to foster a knowledge-based economy and facilitate ICT as a key tool in job creation, economic growth and transparency of governance. The ICT department within this Ministry is responsible for the formulation and supervision of the implementation of the National ICT Policy, facilitating public-private partnership involvement through, for example, the development of ICT parks and national databases to increase access to data and information that supports research and policy development. In addition, the Telecommunication and Postal Services (TPS) Department leads on the implementation of integrated national rural telecommunication programs, including promoting the development of universal broadband as well as satellite broadband access. The Universal Access Division within TPS is responsible for delivering rural telephone and satellite broadband services. Finally, the e-Government Department within the Ministry is responsible for the successful implementation of various e-Government projects, including e-agriculture.

Beyond the Ministry of Communications, the Nigerian Communications Commission (NCC), established under the Nigerian Communications Act 2003[320], is an independent regulatory authority to facilitate competition among operators in the industry as well as provide quality and efficient telecommunications services throughout the country. The Technical Services departments within the NCC oversee emerging technologies and information security while the Stakeholder Management Department manages legal, regulatory, licensing and compliance issues.[321]

Two additional agencies working in partnership with the Ministry of Communications are Nigerian Communications Satellite Ltd (NIGCOMSAT) and the National Information Technology Development Agency (NITDA). NIGCOMSAT owns and operates the Nigerian Communications Satellite systems. Although its first geostationary satellite, NigComSat-1 failed in 2008, the company successfully launched a replacement satellite in December 2011. NIGCOMSAT also provides an anti-counterfeiting system, Olubuster, which uses RFID technology to detect counterfeit products, including in the food industry.[322] NITDA is in charge of fostering the development and growth of IT in Nigeria by regulating, monitoring, evaluating and verifying progress on the goals

xvii The EBA ICT indicator measures laws, regulations and policies that promote an enabling environment for the provision and use of ICT services, particularly in rural areas. The index ranges from 0-9 (9 indicating high performance). An index equal or higher than 4.5 is identified as 'developing' and 'prospering' in the regulatory framework performance and therefore considered as high performers in our cluster

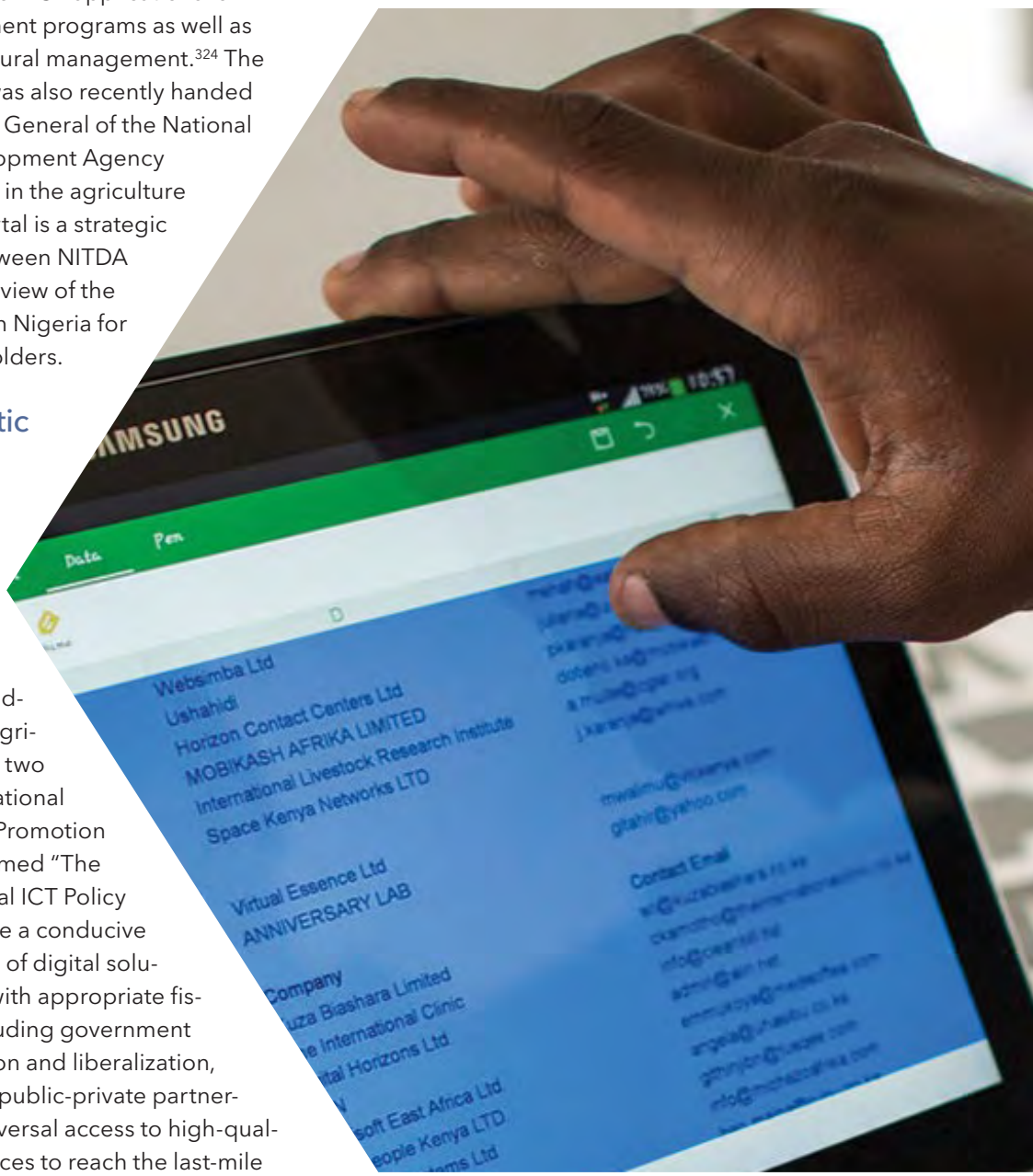
xviii The GSMA Mobile Connectivity Index measures the performance of 163 countries (44 African countries), against the four key enablers of mobile internet adoption – infrastructure, affordability, consumer readiness and content and services. The index ranges from 0-100 with 100 indicating high national capacity to support the adoption of mobile internet.

of the National IT Policy, including fostering competitive local production and manufacture of IT components and improvements in food production and security.

In order to increase the uptake of ICT within FMARD and in relation to agricultural transformation in Nigeria, the Ministry works in close collaboration with the Agricultural and Rural Management Training Institute (ARMTI), a parastatal providing training and development to employees to manage agricultural and rural development projects.[323] Within ARMTI, this responsibility lies with the Agricultural Development Management Department (ADEM) and the Computer Training and Information Management Division (CTIM), which provide training on ICT applications for agriculture and rural development programs as well as effective networking of ICT in rural management.[324] The National e-Agriculture portal was also recently handed over to FMARD by the Director General of the National Information Technology Development Agency (NITDA) to enable swift growth in the agriculture sector.[325] The e-Agriculture Portal is a strategic and collaborative initiative between NITDA and FMARD to provide an overview of the food and agriculture industry in Nigeria for potential investors and stakeholders.

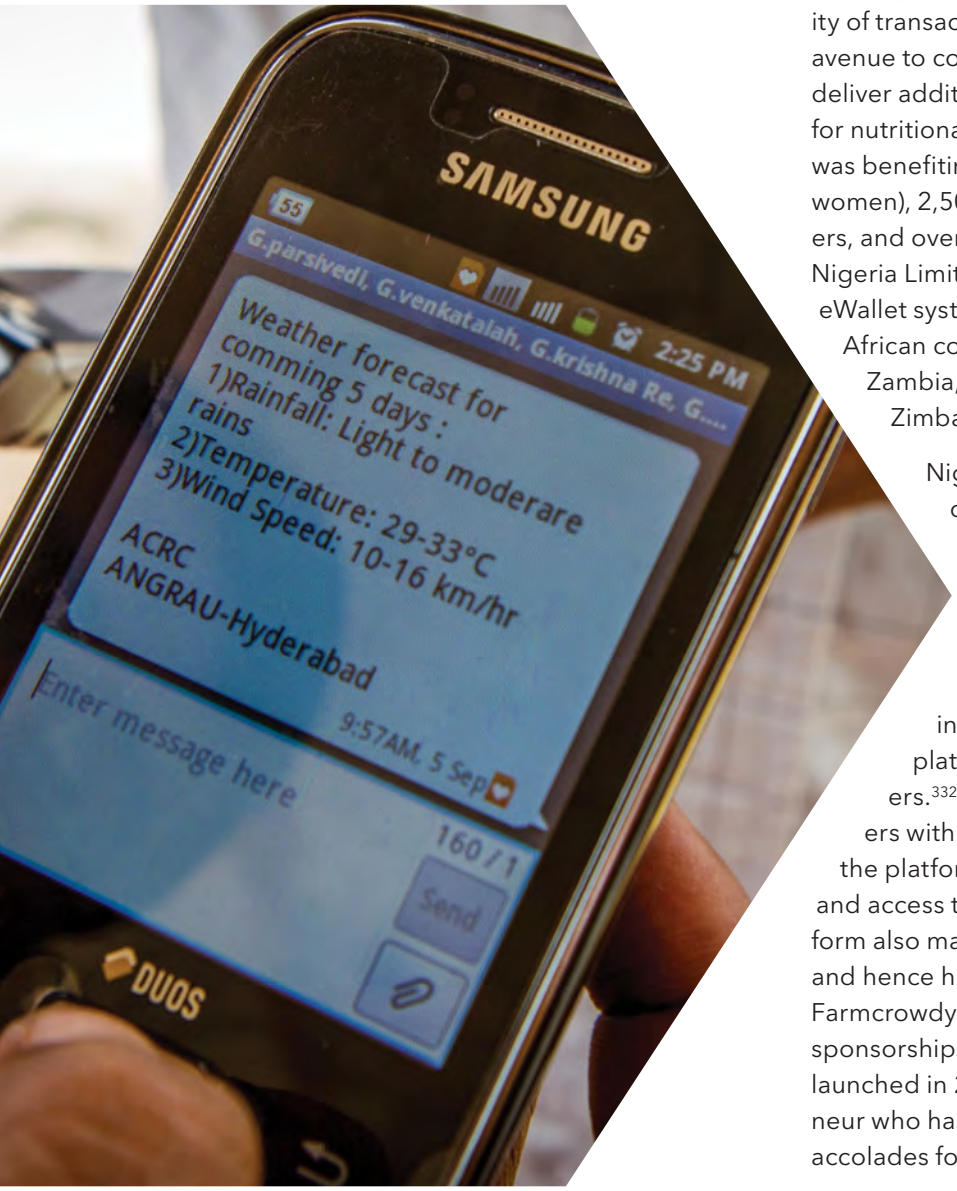
Policy and programmatic innovation

Over the years, the Nigerian government has initiated and adopted several policies to guide the development of the ICT sector and to harness its potential for national development and capacity building. Digitalization in Nigeria's agriculture sector is emphasized in two key policy interventions: the National ICT Policy and the Agriculture Promotion Policy (APP) 2016–2020, nicknamed "The Green Alternative." The National ICT Policy outlines key objectives to create a conducive environment for a rapid uptake of digital solutions in the agriculture sector with appropriate fiscal and financing support, including government budget allocations, deregulation and liberalization, foreign direct investment, and public-private partnerships. The policy promotes universal access to high-quality and advanced ICT and services to reach the last-mile users in rural areas through a program of accelerated deployment of fiber optic networks; by ensuring appropriate security for ICT infrastructure nationwide; and by facilitating access to rights of way (ROW) over public land. The policy also advocates the strengthening of local capacity in ICT technologies and software development.[326] Specifically, the Guidelines for Nigerian Content Development in Information and Communications Technology require equipment manufacturers to maintain at least half local content by value either directly or through outsourcing to local manufacturers.[327] As per Vision 20:2020, the implementation of this strategy is



driven mainly by the private sector, promoting entrepreneurship, innovation and local capacity development, while the government acts as facilitator and catalyst. By promoting the uptake of ICT within the government itself, both the National ICT policy and the guidelines ensure that the development of Nigeria's ICT industry is a bottom-up process.[328]

In addition, the APP acknowledges the importance of access to information and knowledge in enhancing agricultural productivity and improving agribusinesses. The policy focuses on the development of a knowledge system and data center with a focus on weather, input costs and crop prices, as well as improving the reach, effectiveness and efficiency of extension services through the use of electronic means including SMS. APP also promotes the use of economic models, spatial data, GIS, satellite and other data for planning and monitoring of the sector. Finally, APP raises the role of digital mechanisms for supporting land registration processes and invites the research community to leverage digital innovations to lower costs of field work.[329]



To reform Nigeria's input subsidy systems, the government introduced a new digital delivery mechanism, the eWallet program, to manage the delivery of fertilizer and seeds farmers are entitled to; location of the agro-dealers supplying the input; and the amount of out-of-pocket contribution. A transaction confirmation is sent once inputs have been successfully purchased. Not only did this introduce transparency and traceability of transactions, the eWallet program also offered an avenue to contact farmers and was eventually used to deliver additional benefits to farmers, including vouchers for nutritional supplements. By 2017 the eWallet system was benefiting 17 million farmers (many of whom were women), 2,500 agribusinesses, 800 e-extension workers, and over 2,500 service points in Nigeria.[330] Cellulant Nigeria Limited—the company that implemented the eWallet system in Nigeria—now also operates in 12 other African countries—Kenya, Nigeria, Ghana, Uganda, Zambia, Mozambique, Tanzania, South Africa, Zimbabwe, Botswana and Malawi.[331]

Nigeria's drive to engage the private sector in digitalization for agriculture has led to several young entrepreneurs and start-ups investing in hardware and software solutions for the sector, and for various segments of the value chain. One of the first ventures into digital agriculture solutions in Nigeria was Farmcrowdy, a crowdfunding platform connecting potential investors to farmers.[332] The solution matches landowners and famers with capital "sponsors."[333] Farmers enrolled on the platform are also provided with extension services and access to improved inputs. After harvest, the platform also markets the produce to ensure higher prices, and hence higher returns for the investors.[334] As a result, Farmcrowdy has enabled over 11,000 farmers to receive sponsorships from 27,500 investors. Farmcrowdy was launched in 2016 by Onyeka Akumah, a young entrepreneur who has received several national and international accolades for his venture.[335]

CASE STUDY

Nigeria

Hello Tractor is another successful venture by a young entrepreneur. Hello Tractor is an IoT solution to increase and optimize tractor activity in Africa. Founded in 2014, the digital solution seeks to connect farmers to tractor owners through a digital application. Hello Tractor's technology is an off-the-shelf monitoring device that, when fitted onto a tractor, allows equipment owners to manage their machines using an app. Each monitoring device is equipped with an international SIM card, providing GPRS and SMS capabilities for data transmission. Hello Tractor gives smallholder farmers access to machinery which would otherwise be out of reach because of their high cost. Tractors allow farmers to plant forty times faster at one-third the cost and carry produce to market quickly and with less damage, thus reducing postharvest losses. At the same time, tractor owners—who buy them as a source of income too—benefit from improved and coordinated access to farmers and a clear overview on the performance of each machine.[336] The company embarked on a new partnership with John Deere, FMARD and Nigerian Agricultural Mechanization & Equipment Leasing Company (NAMEL), in May 2018 to supply 10,000 tractors over five years. The government leases the tractors to new owners on a pay-as-you-go model (eventually reselling them to the owners at a discounted price), while Hello Tractor provides the telematics solution for monitoring, security and valuation of the tractors, as well as allowing the tractor owners to maintain connectivity and provide a connection for farmers to schedule services for tractors. It is expected that these tractors will bring 9 million ha. of land into production, producing 37 million metric tons of additional food and more than 2 million direct and indirect jobs.[337,338]

To receive financial services, Nigerian farmers are required to register for a Bank Verification Number (BVN), for which it is essential to have a mobile phone. However, in remote parts of Nigeria few smallholder farmers own a mobile phone. To bridge the gap to these last-mile farmers, AFEX Commodities Exchange Limited (AFEX) has developed a platform which, in partnership with the Nigeria Inter-bank Settlement System, creates offline profiles of farmers to generate BVN numbers for them. By May 2019, the company had already reached 20,000 farmers.[339] AFEX was established in Nigeria in 2014 through a public-private partnership with FMARD to establish a warehouse receipt system and commodities exchange for Nigeria. In fact, the electronic warehouse receipt can be used as collateral by the farmers to access financing and is also tradable on the AFEX.[340] By 2016, the company had traded 48,000 million tons of grain, of which 85 percent was maize, reflecting approximately 0.5 percent of Nigerian production, and the rest was sorghum, millet, soybean, peanut, cowpea, ginger and chili.[341]

In 2016, Zenvus, initially funded with grants from USAID and Western Union Foundation, started selling digital solutions and services to Nigerian farmers. Zenvus's products include a solar-powered soil sensor to measure humidity, moisture, nutritional content, temperature, and sunlight. The sensor is equipped with GPS, micro-SD and WiFi, so farmers can monitor changes on their farm remotely. The data is transmitted over cellular and WiFi networks and aggregated on a web-based application.[342]

Zenvus has also developed a hyperspectral imaging camera to track crop nutrition, droughts and outbreaks of pests and diseases. The camera is available in two different versions: one is optimized to work with drones on large farms, and the other is designed to be mounted on a stick allowing the farmer to walk around the farm with it.[343] In addition to the possible improvements in farm practices through the Zenvus products, the collected data also allows farmers to access financing and insurance through the company's different services schemes, zCapital, zInsure, and zCrowdfound. The aggregated, anonymous farmer data is also a key source of income for Zenvus, which it provides to subscribers for an annual fee allowing them to examine potential investments and track performance.[344,345]

It is clear that Nigeria has a prospering enabling environment for digitalization in agriculture. A concerted effort from the most senior levels to transform the economy is driving change at all levels, mapped by Vision 20:2020. The FMCT and FMARD have a clear mandate on infrastructure and regulation and have led on innovative program implementation such as the e-Wallet scheme. The Nigerian government has also developed clear guidelines on private sector engagement in the industry in order to drive innovation and entrepreneurship. Nevertheless, further coordination is required between the government and private sector to ensure that the budding industry delivers maximum benefits and impact to agriculture value chain actors, in particular smallholder farmers. ■

CASE STUDY

Rwanda

The use of digital technologies in Rwanda's agriculture sector is advancing rapidly. Yet, despite visible developments in the ICT sector, Rwanda scored just 3.8 out of 9 in the 2017 World Bank's EBA ICT Index.[xix] While this indicates some progress, there is still room for improvement with respect to regulation and policies that enable a digital environment for the agriculture sector.[346] According to the GSMA 2017 MCI[xx], Rwanda's overall performance regarding key characteristics for mobile internet adoption increased by 27 percent since 2014, with a score of 41.7 in 2017. However, Rwanda still ranks below the African average, mainly due to low network performance and accessibility of mobile apps in the local language. Yet, the country performs particularly well in providing network coverage—with a striking 93 percent of the population having access to 3G networks—affordable handset prices and gender equality in terms of the labor market and gender literacy ratio.[347] While investments in African tech start-ups are primarily concentrated in South Africa, Kenya and Nigeria[xxi], Rwanda has witnessed a growing interest by investors in recent years, with US$36.7 million raised by start-ups in 2017, making it the fourth most popular country for tech investors in Africa south of the Sahara.[348]

Institutional innovation

Through the development and coordination of national ICT and innovation policies, programs and citizen's empowerment, the Ministry of ICT and Innovation seeks to address national priorities for economic growth and poverty reduction. The ministry operates four units dedicated to innovation and business development, digital transformation, postal services, and regulatory services. Furthermore, the development of laws governing the use of ICTs and the prosecution of cybercrimes fall under the responsibility of the ministry. With respect to ICT and innovation, the ministry coordinates efforts with the national Cyber Security Authority, the Rwandan Information Society Authority, and the Rwanda Utilities Regulatory Authority (RURA).[349]

RURA was created in 2001 through law 39/2001 as one of four partner agencies working under the ministry. In 2013, law 09/2013 gave RURA the mandate to regulate telecommunications, broadcasting, information technology and any other audio-visual ICTs. RURA also adopted the International Telecommunications Union ICT Standards and Quality of Service regulation, ICT Scarce Resources Management and Monitoring, Media Regulation, Innovation and Cybersecurity. Under RURA, there are four different subsectors and services.[350] The Innovation and Cybersecurity department was established to ensure the provision of faster, more secure and better online services in all sectors, including the agriculture sector.[351] The department, strengthened by the 2016 ICT law, operates six different schemes, namely big data, information application, emerging communication technologies, cybersecurity, internet governance and an innovation fund. Overall, the department is responsible for implementing the requirements of the different sectors such as emerging technologies, big data, fintech, IoT, e-agriculture, e-commerce and internet governance.[352]

Within the Ministry of Agriculture and Animal Resources (MINAGRI) the General Directorate of Corporate Services coordinates, manages and assesses the status and usage of ICTs in the agriculture sector.[353] MINAGRI also cooperates with the Ministry of ICT and Innovations and their implementing agency, the Rwanda Information Society on some of their ICT projects, including the e-Soko service for farmers.[354]

Policy and programmatic innovation

Rwanda has been embracing an ICT transformation since 2000, with an ambitious National Information Communications Infrastructure (NICI) policy, which outlines a long-term plan to achieve full digitization in four stages of five years each. The NICI plan was also integrated into Vision 2020, the government's comprehensive program to transform Rwanda into a middle-income country by 2020. The first stage of the NICI (2000–2005) laid the basis for a thriving ICT

xix The EBA ICT indicator measures laws, regulations and policies that promote an enabling environment for the provision and use of ICT services, particularly in rural areas. The index ranges from 0-9 (9 indicating high performance). An index equal or higher than 4.5 is identified as 'developing' and 'prospering' in the regulatory framework performance and therefore considered as high performers in our cluster.

xx The GSMA Mobile Connectivity Index measures the performance of 163 countries (44 African countries), against the four key enablers of mobile internet adoption – infrastructure, affordability, consumer readiness and content and services. The index ranges from 0-100 with 100 indicating high national capacity to support the adoption of mobile internet. Rwanda's MCI score was 31.6 in 2014 and 40.0 in 2017.

xxi Investments in South Africa, Kenya and Nigeria accounted for 76 percent of all total funds raised by start-ups in SSA in 2017.

Rwanda

sector, including the design of institutional, legal and regulatory frameworks, as well as liberalizing the telecommunication market by reducing entry barriers to encourage domestic and foreign direct investment and competition in the sector. During the NICI's second stage (2005–2010)[355], the focus was on enhancing ICT infrastructure by establishing a national data center that provides information storage, management and protection, using cloud computing opportunities. In addition, a national fiber-optic backbone network connecting Rwanda to international sea cables was deployed, increasing internet accessibility and affordability. In the third NICI plan (2010–2015), the focus was on the development and improvement of ICT services. The current and fourth stage, the Smart Rwanda Master Plan (2015–2020), seeks to propel Rwanda's economic development and to meet the goals under Vision 2020, in particular through increased ICT capability and capacity, secure and shared infrastructure across the public sector, and an institutional governance structure for integrated and centralized management of ICT strategy.[356] [357]

With respect to the agriculture sector, Rwanda is currently implementing the third cycle of its National Agriculture Investment Plan (NAIP), the Strategic Plan for the Transformation of Agriculture in Rwanda (2018–2024). The country's first NAIP (2008–2013) focused on increasing agricultural outputs and incomes for all farmers and indicated the need for ICTs to strengthen institutional structures. The plan further aimed at strengthening the collection and analysis of statistical information on crop production, the creation of a sectorwide ICT system including the development of real-time market information and a network of local meteorological stations, and setting up community innovation and farmer training centers. To establish a sectorwide ICT system, US$3.3 million were allocated between 2008 and 2012.[358] During that time, extreme rural poverty fell from 39.5 percent to 26.4 percent due to interventions that aimed to move the agriculture sector from subsistence to a market economy. Rwanda's second NAIP (2014–2018) was designed in the spirit of transforming Rwanda's agriculture from a subsistence to a market-oriented, value-creating sector. The use of ICTs was encouraged at several stages, including the establishment of soil information systems using GIS, strengthening the quality and communication of weather forecasts, collection of cow production data for crossbreeding, and provision of digital platforms to improve information provision and mainstreaming related to regional and international trade through the digital service e-Soko. The third NAIP (2018–2024) aims to further increase wealth and prosperity of those living in rural areas.[359]

In 2016, MINAGRI launched the National ICT Rwanda Agriculture (ICT4RAg) Strategic Plan (2016–2020) with the objective of transforming agricultural practices. Its focus is on providing information to enhance productivity and ICT-based agricultural commercialization and to establish industrialization within the entire value chain.[360]

Prior to this, in 2007, MINAGRI and the Rwanda Information Society in collaboration with the Mobile Telecommunication Company (MTN) had launched e-Soko, Rwanda's Agricultural Market Pricing Information System, providing farmers in rural areas with market and price information on different crops, including beans, maize, rice, wheat, potato, and cassava. E-Soko allows farmers to access daily price quotes of different commodities through text messages received in their local language. Farmers without mobile phones can access e-Soko via village phones—smartphones owned by extension agents and provided to farmers to access services. Data on commodities are also used by officials

to forecast market trends. By 2015, the e-Soko platform provided information on 78 commodities in 61 markets across Rwanda.[xxii] Earlier in 2011, the platform won the Technology in Government in Africa (TIGA) Award.[361] E-Soko is still being used widely across Rwanda and plans for an updated version, e-Soko+, have been released in the ICT4RAg indicating an additional investment of about US$4.2 million in the project until 2020. E-Soko+ aims to combine market price information, currently provided through e-Soko, with an online trading platform.[362]

In order to increase access to agricultural information, knowledge and markets, the government has opened 92 ICT centers countrywide. The centers aim to provide farmers with relevant information on agriculture-related topics by providing computer and internet access, and other services, including scanners, printers and photocopiers at low prices. While 30 of the centers are privatized, 62 remain under district management.[363]

Furthermore, the private sector plays an active role in the agricultural digitalization process, offering various online services across the value chain. Access to Finance Rwanda and TransUnion Rwanda launched Menyesha (meaning "inform me") as a pilot project in 2017. By determining farmers' creditworthiness through the use of credit-scoring tools offered by financial service providers, the project aimed to reduce risks for rural communities, including smallholder farmers. Menyesha is a digital tool that allows users to check their credit status by simply sending a SMS or USSD. The credit status is then sent to the potential lender via SMS specifying a "good" or "default" status, indicating the ability to pay back a loan on time and the associated risk to a

xxii Information provided by MINAGRI.

borrower. On request, the user can also get the report, listing credit history payment behavior in terms of on time payments and personal details including name, ID number, address, and employer. The credit report fulfills two objectives. For the user, seeing the amounts of debt and outstanding payments at any particular time helps to resolve credit problems as Menyesha further supports transactions to various lenders and financial institutions directly via mobile money. Once debts are settled, users can decide to give permission for credit grantors to view the credit report if they apply for a loan. Since access to finance is a persistent problem for smallholder farmers in Rwanda, this tool can help farmers to build their digital identity and create trust. The initial pilot was targeted to serve 8,000 users within two years. However, the target was surpassed within just nine months, reaching over 9,700 people.[364,365]

Based on the ambitious plans under the NAIP and the ICT4RAg, MINAGRI has implemented different projects related to the use of ICT in the agriculture sector, including an online exchange platform for all stakeholders of the agricultural and livestock sector (AMIS) and an online trade management information portal, the Rwanda Agricultural Livestock Inspection and Certification services (RALIS), facilitating international business and trade.[366] Given the country's topography with many hills and steep slopes, arable land is scarce in Rwanda and solutions to optimize land use are urgently needed. Based on the completed national land registry in 2012 and the mapping of 10.3 million parcels, 24,000 ha belonging to MINAGRI were found suitable for agricultural purposes. The Agriculture Land Information System (ALIS), implemented with support from USAID, is an open-source platform accessible through computers, tablets or smart phones that visually maps public land available for investment. The real-time online tool, which aims to attract private sector investments into agriculture, further provides information on plot size, general soil type, current use, proximity to infrastructure and agro-climatic conditions.[367] In collaboration with FAO, MINAGRI is currently developing a digital portfolio with five mobile services (weather and crop calendar; e-Nutrifood; cure and feed your livestock; agri-market place; and fall army worm monitoring system) with the objective of providing rural farmers with a better and more equitable access to agricultural information and knowledge, productive resources, services and markets using ICT.

In addition to existing projects, MINAGRI identified three different flagship projects that aim to further strengthen the agriculture sector through the use of ICT solutions. One of the projects is the Farm Management and Information System (FMIS), which serves as the backbone system for all other services. Through data collection, FMIS aims to enable communication and information exchange with external actors, such as providers, value chain actors and government authorities. A second project is the updated version of the already existing e-Soko platform, e-Soko+. The new version aims to improve the existing agriculture marketing services and lead to improved food security. As a third flagship, the ministry is developing several Mobile-Telephone Enabled Agriculture Technology Apps, including e-Growers information Management System, e-Inputs, e-Agri-Wallet, e-Trace Dairy, and e-Information. Overall, the ministry has allocated about US$15 million to the flagship projects until 2020 and aims for the private sector to finance additional ICT projects with estimated costs of US$22.7 million.[368]

With support of US$10 million from the AfDB, the Rwanda Development Board (RAB) finished the construction of a new campus for the Carnegie Mellon University (CMU) Africa in 2019. The new CMU campus aims to provide better teaching and learning experiences to students and addresses the issue of limited capacity in hardware and software engineering, network design, and large-scale ICT project management in Africa.[369] Currently the university offers two master's programs, one in electrical computer engineering and one in information technology.[370] The 15-hectare CMU campus is one of the first facilities being completed on the land of the government's Kigali Innovation City (KIC), a public-private partnership between the government and Africa50 aiming to attract universities, technology companies, and biotech firms, as well as commercial and retail real estate. The KIC project aims to become a leading African tech hub, valuing about US$2 billion, and expected to create over 50,000 jobs and generating US$150 million annually through the export of ICTs.[371]

Rwanda has a rapidly developing environment for digitalization in agriculture. The government's dedication to increasing the uptake of digitalization in agriculture is evident as it puts in place clear and well-financed policies and mandates for ministries. As the sector develops, there will be more room for the private sector to play an active role. ■

CASE STUDY

Senegal

The Government of Senegal has shown clear commitment to promoting greater ICT penetration and provision of ICT services, including in the agriculture sector, through carefully designed policies and regulations. The country's EBA ICT score[xxiii] of 4.5 out of 9 indicates a strong enabling digital environment with regard to laws, regulations and policies, while its score of 37.3 in the GSMA MCI[xxiv] reflects relatively good performance on the affordability of connections and handsets, as well as network coverage. This achievement is largely due to the government's commitment at institutional and programmatic levels to create an enabling environment for digitalizing its economy, including the agriculture sector.

Institutional innovation

Several institutions in Senegal are responsible for ICT development. The Ministry of Digital Economy and Telecommunications promotes the penetration of ICTs and their application in all sectors of the economy through the Directorate of Information and Communication Technologies (DTIC). DTIC implements the government's policy related to digitalization, which includes research and development of technologies and applications aimed at reducing the digital divide across the country and accelerating the competitiveness and growth of businesses.[372] In 2001, the Regulatory Authority for Telecommunications and Posts (ARTP) was created as an independent administrative authority with legal status and financial autonomy to regulate the telecommunications and postal sectors, including compliance with national competition law. Furthermore, in 2004 the *Agence de l'Informatique de l'État* (ADIE) was created to increase the use of ICTs within the Senegalese Administration. It provides citizens and businesses with a decentralized interface to access information on services provided by the government, thus reducing social exclusion. In addition, ADIE seeks to establish a reliable information system for effective monitoring of government programs. ADIE also coordinates the establishment of legislative and regulatory frameworks conducive to the development of ICTs in the public sector.

In 1997, Senegal put in place a legislative and regulatory framework to promote the use of ICTs while minimizing their risks, including cybercrime.[373] This facilitated the entry of new mobile network operators. Mobile broadband connections are also growing rapidly, as 3G and 4G coverage is expanding at almost 63 percent per year.[374] Between 2000 and 2017, the share of population using the internet increased from less than 1 percent to 59.38 percent.[375] In 2001, the government introduced the universal service law in the telecommunication code to finance and subsidize selected ICT services for the most marginalized and poor segments of the population, in order to ensure that they benefit equally from access to the internet and new digital technologies. As a result, Senegal complies with the 2007 ECOWAS Additional Act, which stipulates access to a minimum set of services at affordable rates throughout the region. These include telecommunications services, such as access to telephone directories and public pay phones.[376] Furthermore, in 2008, Senegal created the Commission for the Protection of Personal Data, which is an Independent Administrative Authority. It ensures that the processing of personal data is carried out in accordance with legal provisions and informs without delay the public prosecutor of the offenses of which it is aware.[377]

Policy and programmatic innovation

While investment in ICT infrastructure was low prior to 1977, the Fifth Economic and Social Development Plan in 1978 launched a new phase of ICT infrastructure development, lasting until 1990. A vigorous boost in public investment, with a focus on ICT development, meant that in just one year, the investment in telecommunications as a share of total public investment increased from 2.5 percent to 5.7 percent. However, starting in the 1990s, public investment in ICT sector decreased significantly due to the severe economic crisis affecting the country. Over just one year from 1989 to 1990, investment fell from US$22.6 million to US$8.9 million—an amount comparable to that of 1978. The decline continued further until 1995, when public sector investment in ICTs infrastructure fell

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to 1.4 percent of total investment. However, since 1997, with the adoption of a more liberalized approach, new opportunities have emerged for the private sector to invest in the ICT sector infrastructure.[378]

In addition to investment in infrastructure development, programs facilitating access to ICTs began to be implemented across the country. Since the late 1990s, the Multimedia Community Centers (CMCs) project—initiated by UNESCO, the Swiss Agency for Development and Cooperation (SDC) and the government of Senegal—has been driving efforts to reduce the digital divide. The project sought to connect rural and marginalized communities to the internet and ICTs such as community radios and computers. Twelve new radio frequencies, 13 radio stations and 20 cybercafes were opened through the project. The project has also trained more than 730 people in radio production, computer usage, the internet and multimedia, and administrative, technical and financial management of Multimedia Community Centers.[379]

In 2007, Senegal created the Universal Telecommunication Service Development Fund (FDSUT) to provide financial support to any public agency for the provision of ICT services. The FDSUT also finances the extension of telephone and internet services to rural and urban areas to improve their social and economic integration and ensures that the beneficiaries are involved in the development and provision of services to meet their specific needs. Furthermore, the FDSUT promotes entrepreneurship to make ICT services available in rural areas.[380] Through the funding from FDSUT, innovative ICT solutions are now being developed for the agriculture sector, such as DARAL Technologies.

DARAL Technologies was created in 2014 by young entrepreneurs to support farmers dealing with livestock diseases and theft. The project uses traceable nose rings on livestock to monitor, track and communicate about herd movement through SMS alerts. The technology is also used by individuals or organizations that are looking to buy or sell livestock, allowing them to secure their transactions. By 2016, DARAL had been active in 10 villages in southern Senegal, equivalent to 2,553 farmers. There are plans in place to bring DARAL to scale in collaboration with the Ministry of Agriculture.[381] The government's Digital Senegal 2025 strategy has guided the dissemination of digital technologies in all sectors of the economy since 2016. With respect to the agriculture sector, the strategy seeks to improve productivity through easier access to information on prices, soil quality, weather and new farming techniques via mobile and internet. To do so, the government is implementing a system to modernize agricultural activities by developing mobile telephone, GIS, and satellite imagery-based applications to allow forecasting throughout the production cycle, send shocks alerts, raise awareness on prevention measures and provide geolocation of livestock.[382]

To support the Government of Senegal's objectives of reducing poverty and food insecurity among its vulnerable rural populations, USAID launched the Feed the Future Senegal Naatal Mbay Project ("Flourishing Agriculture" in Wolof), funded under the US Global Food Security Act. The project aims to scale up and expand successful technologies, skills and approaches for inclusive growth and resilience in rice, maize and millet value chains. GPS-enabled devices were introduced to farmers to measure their fields accurately. With accurate measurements, they can purchase the correct amounts of seed and fertilizer. Farmers were also taught to track planting methods, timing, spacing, and rainfall. In addition, the program installed automated rain gauges in farming areas, allowing insurers to quickly and accurately determine farmers' losses and set crop insurance payments. Naatal Mbay's key contributions include: a 15 percent reduction in rice imports by Senegal in 2016, increased use of state-of-the-art farm equipment, such as tractors and harvesters, enabling more efficient harvests, and a threefold increase in crop yields among women growing upland rice in the formerly conflict-ridden Casamance region.[383]

With respect to the private sector, there is evidence that an enabling digitalization environment is leading to a more effective uptake of digital technologies and services in the agriculture value chain. Since 2001, Manobi has been providing digital services through mobile phones to farmers, fishermen and agribusinesses to strengthen their position in national and international markets. For fishermen, services include geolocation, a safety program using GPS/GSM, and a weather and tidal information service for fishermen. Manobi also operates Xam Marsé—a platform that allows farmers to share knowledge and information and receive business support through crop monitoring services and market information on prices, as well as sell their produce. The database is fed by real-time information on prices for main crops and products according to variety, origin and packaging. After a successful phase of testing the system with horticulturists in Sébikotane, a

rural community near Dakar, the company expanded the service to other regions across Senegal.[384] Manobi is now active across West Africa, including in Mali, Côte d'Ivoire, Benin, Niger and Burkina Faso.[385]

In 2017, Bayseddo was launched—a digital platform to connect farmers and land owners to investors seeking to invest in farming. Large shares of arable land remain unfarmed across the continent due to a lack of sufficient capital, while at the same time, there is a growing number of investors interested in investing in the agriculture sector. Since its launch via Bio-Agripôles, Bayseddo has facilitated four agricultural partnerships in the region of Saint-Louis, farming 18 ha of land. The company has generated US$130,000 and created 20 jobs so far.[386] In 2017, the Bayseddo won a prize of US$15,300 from CTA to scale its operations.[387]

The Senegalese government has steadily increased the dissemination of ICTs through institutional and programmatic innovations over the past years. This has contributed to an increased uptake of digital services and tools for the benefit of the whole economy including the agriculture sector. The quality and extent of ICT infrastructure due to the growth in national ICT expenditure since the 1980s and the subsequent liberalization, the availability of human resources and the entrepreneurial spirit of a growing number of young Senegalese have fostered the digitalization in the economy. Yet, despite these achievements and initiatives by the government and international organizations, more effective cooperation with the private sector is needed to be able to harness the opportunities of digital technologies for the agriculture sector. ■

7. Conclusion

The use of digital technologies, platforms and services in the agriculture sector can be an opportunity for African countries to leapfrog and create smart agriculture value chains through digitalization. There is a particular role for Africa's young people to develop new digital technologies and innovations that will allow the continent to become a frontrunner in using digital technologies and services to tackle some of the biggest challenges the agriculture sector faces, such as climate change, demographic changes and food and nutrition insecurity. In addition to the design and development of cutting-edge digital agriculture technologies and services, it can be expected that in the coming years, investments in agricultural digitalization by governments and the private sector will continue to increase while mobile internet connectivity and data availability will continue to improve, further boosting real-time solutions.

While the African digital sector is transforming at a rapid pace—witnessing the fastest global growth of mobile subscribers over the last decade—new digital innovations that have the potential to leapfrog could further speed up Africa's agricultural transformation. Although longer-term developments in digitalization are difficult to predict, new technologies like harvesting robots, lightweight sites for connectivity, solar-powered charging points, aerial balloons to provide internet to remote communities, or locally produced smartphones can contribute to leapfrogging some of the major limitations, particularly with regards to building last-mile infrastructure. To provide the ecosystem that the private sector, including smaller start-ups, needs for innovation to flourish and to drive agricultural transformation, further long-term public investments in infrastructure, digital skill development and smart regulations are urgently required. This investment needs to be coupled with ongoing evaluation and impact assessments to highlight gaps and opportunities for further skill development and research.

One strategy to realize the continent's potential is to replicate and scale up successful interventions that have worked on the ground in African countries. Doing so in a critical mass of countries across the continent would help meet the targets and goals under the African Union's Agenda 2063 and the Malabo Declaration. Several common features distinguish those African countries that have made significant progress in developing digital tools and services for the agriculture sector. The case studies have shown that success has been most effective where governments have created a strong enabling digitalization environment, including a sound regulatory and fiscal regime, coupled with a growing role for the private sector in the design, development and dissemination of innovative, smart technologies and an innovation ecosystem that particularly encourages young people to develop locally adapted digital solutions and services.

In Côte d'Ivoire, strong legislation ensuring universal access to ICTs and a favorable fiscal regime with a zero percent customs duty and exoneration of VAT on ICTs, combined with digital financial services and an e-agriculture strategy, have facilitated the use of digital technologies and services in the agriculture sector. Ghana has been performing particularly well in devising an enabling environment for the use of digital technologies with strong legislation safeguarding personal information and data privacy, in addition to an extensive use of digital platforms and services, such as Esoko, e-Agriculture and e-Farm and the provision of Community Information Centers to provide e-government services to rural areas. Kenya, on the other hand, stands out for an extensive use of digital platforms and services for the agriculture sector, with an e-voucher system to purchase agriculture inputs, knowledge hubs, Tech-labs, and ICT centers to build and strengthen the capacity of the country's youth. In Morocco, strong institutions and policies, including a dedicated Agency of Digital Development, as well as the Digital Morocco Plan and membership to the WTO Information Technology Agreement mean that the country has created a strong enabling and business environment for the digitalization of its economy. Agriculture-focused digital platforms and satellite technology also mean that Morocco is at the forefront of providing cutting-edge digital technologies for use in the agriculture value chain. Nigeria has a thriving digital entrepreneur and start-up environment, enabled through a strong institutional infrastructure with several agencies dedicated to digitalization and promoting the local manufacture, capacity and content development of ICTs. In addition, ICT parks across the country facilitate access to information and data even in remote areas. Similarly, Rwanda has an ambitious pipeline of digital platforms and services aimed to reach scale, coupled with close-to-universal 3G coverage and strong institutions and ICT laws governing big data, financial tech and e-agriculture services, among other. Rwanda's Information Communication Infrastructure Policy sets out the country's long-term plan and vision for digitalizing its economy, while ICT centers provide farmers with information on agriculture-related topics. Finally, in Senegal, targeted legislation on the protection of personal data and a supportive fiscal regime

with subsidies on selected ICT services for the most marginalized, coupled with a long-term vision under the Digital Senegal 2025 Strategy mean that the uptake of digital technologies and services is developing rapidly.

The experience of the seven African countries analyzed in this report can help other African governments develop country-specific strategies to increase resilience and improve livelihoods in Africa's rural communities and beyond. The Malabo Montpellier Panel has identified a set of policies and practices summarized below that, if brought to scale, could significantly improve the resilience and livelihoods of rural communities and spur overall agricultural growth and transformation in Africa.

RECOMMENDATIONS

1. Placing digitalization at the core of national agricultural growth and transformation strategies and policies.
2. Creating a transparent and smart regulatory environment that promotes the development and confident use of digital technologies and services and limits the risks.
3. Expanding university curricula to spur digital innovation and the development of an African agtech sector.
4. Strengthening skill development and digital literacy training for farmers and other actors in the food system as technologically more advanced innovations are being developed.
5. Increasing investment in R&D to develop both frugal and cutting-edge digital solutions that meet the demands of all actors and at each segment of the food value chain.
6. Introducing fiscal incentives to spur digital innovation and to facilitate market entry and the import of technologies until local markets are developed.
7. Investing in supportive and last-mile infrastructure to bridge the digital divide.
8. Developing digital agriculture innovation hubs to create an innovation ecosystem for young people to develop locally suitable technologies and digital solutions.
9. Carrying out evaluation and impact assessments of specific technologies and e-services in rural areas to highlight gaps and opportunities for further skill development and capacity strengthening.

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