Chapter 18

DIGITAL INNOVATIONS AND AGRICULTURAL TRANSFORMATION IN AFRICA: LESSONS FROM KENYA

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Digital innovation is a key feature in the global and national discourse on food systems transformation. Efforts to better integrate food systems—defined here as the constellation of actors and their activities originating from agriculture, livestock, forestry, or fisheries, as well as the broader economic, societal, and natural environments in which they operate, including the production, aggregation, processing, distribution, consumption, and disposal of food products (Dwivedi et al. 2017; FAO 2018; Njuki et al. 2021)—will depend partly on how digital technologies can be used to bolster engagement, coordination, and innovation among a wider and more inclusive set of actors, including marginalized and vulnerable groups (Benfica et al. 2021).

Small-scale and resource-poor farmers are one such marginalized and vulnerable group, particularly within emerging African food systems. Already, there is rapidly growing enthusiasm around the potential of digital tools to transform smallholder agriculture, with substantial attention being paid to the opportunities in public policy discourse throughout Africa. The rapid spread of mobile phones and growing internet penetration in low- and middle-income countries, as well as promising evidence on positive impacts, justify this enthusiasm. In the past few decades, many public and private sector initiatives have been launched with the objective of building digital tools to transform smallholder agriculture in developing countries. These initiatives have led to the proliferation of digital innovations that aim to address smallholders' information, skills, and market constraints. These digital innovations mostly aim to address alternative forms and sources of market failures as well as institutional delivery bottlenecks.

Several evaluations show that digital innovations have considerable potential to revolutionize smallholder agriculture in Africa and, in particular, in Kenya (Kikulwe, Fischer, and Qaim 2014; Baumuller 2018; Abay et al. 2021; Benfica

et al. 2021). Kenya was an early beneficiary of the boom in digital innovations to support smallholder agriculture in Africa. Pilots aiming to experiment with various digital innovations in sub-Saharan Africa are disproportionally centered in Kenya (CTA 2019). As such, Kenya has important lessons to offer many African countries on both how to leverage digital solutions to support smallholder agriculture and how to attract investment in digital innovation.

Despite these signs of progress, many digital innovations targeting smallholder farmers in Kenya—and in Africa more generally—remain in the pilot stage, with limited success at scale. In spite of encouraging results from the evaluations of these pilots, realizing the potential of digital development for agriculture requires much more investment and learning from large and successful scaling-up efforts. Indeed, many digital innovations targeting smallholders in developing countries fail to scale up (World Bank 2016); those that do scale up fail to be sustainable. While the engagement of the private sector in building digital innovations continues to be encouraging, national agricultural agencies and related institutions in many African countries are simply not changing at the pace that the digital revolution demands. The critical disconnect between pilots and scale-ups of digital tools targeting smallholder agriculture, as well as the lack of integration of these innovations within national agricultural systems, is likely to define whether smallholders can benefit from the digital revolution. These limitations apply to Kenya as well as to many other countries in Africa, albeit to different extents.

This chapter reviews existing digital innovations targeting smallholders in Kenya with the objective of drawing lessons that can benefit future scale-ups of digital innovations in Kenya and the rest of Africa. Our review aims to identify encouraging developments as well as important pitfalls that inhibit realization of the promise of digital innovations to transform smallholder agriculture in Kenya and in the region.

The chapter first briefly presents the landscape of digital innovations in Kenya. It then documents Kenya's success in the digital space by highlighting unique features in its digital ecosystem, including policies and regulatory systems. What follows highlights the disconnect between pilots and scale-ups of digital innovations in Kenya by exploring potential challenges and enabling factors. The chapter concludes with some lessons that the rest of Africa can learn from Kenya in digitalizing agriculture.

The landscape of digital innovations in Kenya

Several types of digital innovations have so far been used to support Kenya's agricultural and food system transformation. Some of these innovations have

been used to support agricultural extension, market access and linkages, and various farm coordination activities, like the distribution of farm inputs and equipment. In particular, many of these innovations have been instrumental in reducing information and search costs through market advisory and information systems. Beyond these production- and market-geared solutions, Kenya has also made significant strides in introducing and scaling up digital innovations that provide digital financial services (Suri and Jack 2016; Suri 2017). The functionalities of these innovations have evolved over time, and there is now momentum behind the innovation process to continuously respond to the dynamic nature of Kenya's agriculture and food sectors.

This section develops a typology of digital innovations to examine six specific categories that are relevant to the Kenyan experience. The typology is drawn from a repository of relevant digital innovations, presented in Appendix 18.1. While some of the categories overlap in terms of definition, and certain digital innovations may fall in more than one category, given their multiple functions, the typology itself is nonetheless useful in organizing and structuring both national and global experience in a rapidly changing field.

Agricultural extension and advisory services

The digital innovations in this category mainly offer agronomic advisory services to farmers and aim to accelerate technical changes in food production systems. They mimic the typical agricultural extension and advisory services prevalent in many rural settings, sometimes functioning as a substitute and sometimes as a complementary service or an integrated augmentation of conventional services. They often focus on increasing agricultural production and productivity by tackling key production constraints facing farmers. For instance, iCow aims to improve productivity and profitability by providing extension advice and training on proper ways of raising livestock (Daum et al. 2022). Similarly, DigiCow addresses key production issues in the livestock sector like poor disease management and inbreeding.

In terms of how they function, some of the digital innovations in this category, such as iShamba, operate as call centers: interested farmers can dial in to speak to experts on a range of issues affecting their farm and livestock production. In doing so, farmers also receive additional information such as market prices and weather updates. Additional examples of digital innovations that provide extension and advisory services for farmers in Kenya include Arifu, M-shamba, and Viazi Soko. Other applications, like Digital Green and Kuza Biashara, are leveraging video extension services. Given the inability of public extension systems to effectively meet farmers' demand, there is increasing

interest in revamping extension provision through public–private partnerships. Currently, many county governments are establishing links with applications like DigiCow to enable public–private extension.[1]

Weather information and services

In the face of weather and climate vagaries, digital innovations in this category disseminate information to farmers on weather patterns and events, including forecasts and long-term predictions. For instance, using the Kenya Agricultural and Livestock Research Organization's (KALRO's) Kenya Agricultural Observation Platform (KAOP) and the Climate, Livestock, and Markets (CLIMARK) project's MyAnga application, farmers can monitor rainfall and weather patterns through their mobile phones (CTA 2020). Beyond weather and climate information, some of the digital solutions in this category provide support to farmers by addressing energy and irrigation needs. An example is SunCulture, which uses off-grid solar technology to provide farmers with reliable access to water, irrigation, lighting, and mobile charging. Some of these applications also have the ability to combine solar water pumping technology with high-efficiency drip irrigation to enable farmers to improve production and land productivity.

Market information systems and linkages

Digital innovations in this category disseminate information about market prices and link buyers to sellers as well as importers and exporters of agricultural commodities. Some of them also act as a marketplace where buyers can source food and agricultural produce. They form the bulk of the category of agricultural digital innovations in Kenya. Their main objective is to reduce information asymmetries associated with selling and buying agricultural commodities. Typically, they reduce some aspects of transaction costs, enabling parties involved in trading to realize optimal gains. An example is M-Kilimo, founded and deployed in 2009 to reduce the informational constraints facing farmers in horticultural value chains (Misaki et al. 2018). Other applications in this category include iCow, N'Kayo, iShamba, Kenya Agricultural Market Information System's Kilimo, SunCulture, iProcure, DigiFarm, E-Tinga, Farmers Pride, Farmshine, Herdy Fresh, Kitchen, Soko, Mifugo.trade, Selina Wamucii, Taimba, TruTrade, Tulaa, Twiga Foods, Jumia, and Kuza Biashara.

1 This is mostly carried out under the government's Kenya Climate Smart Agriculture Program and the National Agricultural and Rural Inclusive Growth Project. The World Bank is also a partner here and facilitates financial support and partnerships between counties and private companies (for example, SunCulture, DigiCow, Apollo, Hello Tractor, One Acre Fund, and Kuza Biashara).

Digital financial services (intermediation and payment systems)

Digital innovations in this category often aim at facilitating financial transactions between trading actors. This usually takes the form of mobile money transactions. These are cashless payments, reducing the uncertainties and risks associated with market exchanges. Some of the digital innovations under this category act as physical banking and microfinance institutions that offer savings, loans, and credit facilities to farmers. Relatedly, they also offer financial management services through transparent and traceable transactions. The applications in this category have the potential to revolutionize smallholder agriculture as they have been critical in spurring financial inclusion (Suri 2017; Bharadwaj and Suri 2020). A typical example and success story has been M-Pesa, a mobile financial service that has been widely scaled up in Kenya. However, these financial services are underused in agriculture and do not seem to be having a transformative impact on the sector as yet (Parlasca, Johnen, and Qaim 2022). M-Pesa also has linkages and facilitates the services of various agriculturally geared programs and activities. For instance, it is used to facilitate the enrolment and payment of claims of index insurance services provided by the Agriculture and Climate Risk Enterprise. Another example of an application rendering financial services is M-Shwari, Kenya's most popular digital banking platform. Other examples under this category include DigiCow, Apollo, Dodore, FarmDrive, Musoni, Virtual City, and Mastercard Farmers Network.

Supply chain coordination (agricultural inputs and services)

The digital innovations in this category aid in various farm planning and coordination tasks. They cover production system management, sales and inventory management, and bookkeeping in farm production. They also ease access to various inputs, such as seeds, fertilizers, and agricultural machinery. An example here is the National Potato Council of Kenya's Viazi Soko, a digital platform that provides an efficient way to access quality farm inputs and services such as certified seeds, fertilizer, and mechanization services, among others (Parker 2021). The web-based portal and mobile-based application enable farmers to book and place orders for farm inputs as well as to receive accurate agronomic information and other services geared to improving productivity and profitability.

Another example worth mentioning is Smart Cow, which operates as dairy management software. It records important biographic details about livestock, such as on birth and pedigree, insemination, breeding, deworming, vaccination, and deaths as well as postmortem records. Other examples in this category

include MTela, Apollo, DigiCow, M-shamba, E-Tinga, FarmIT, Tulaa, and Budget Mkononi.

Data and crowdsourcing services

This category of digital innovations responds to the increasing need for quality and real-time data to answer policy-oriented questions with regard to agricultural transformation (Benfica et al. 2021). These tools collect data using crowdsourcing and remote data collection methods. They thus offer the possibility of multiple data usage options, such as predictions and forecasting, which are relevant in informing policy decisions. Compared with the above-mentioned categories, these innovations are still at the early phase of development and deployment. They provide the basis for evidence-based policies by developing opportunities to source data from farmers. An example in this category is KAZNET, which sources livestock-related information from pastoralists in Kenya (Graham et al. 2021). Akin to the first category (agricultural extension), they also offer peer-to-peer engagement and expert support with the possibility of feedback loops. Closely related examples here include Nuru, DigiCow, and KAOP, which crowdsource data and share these to input suppliers to help them meet farmers' demand effectively.

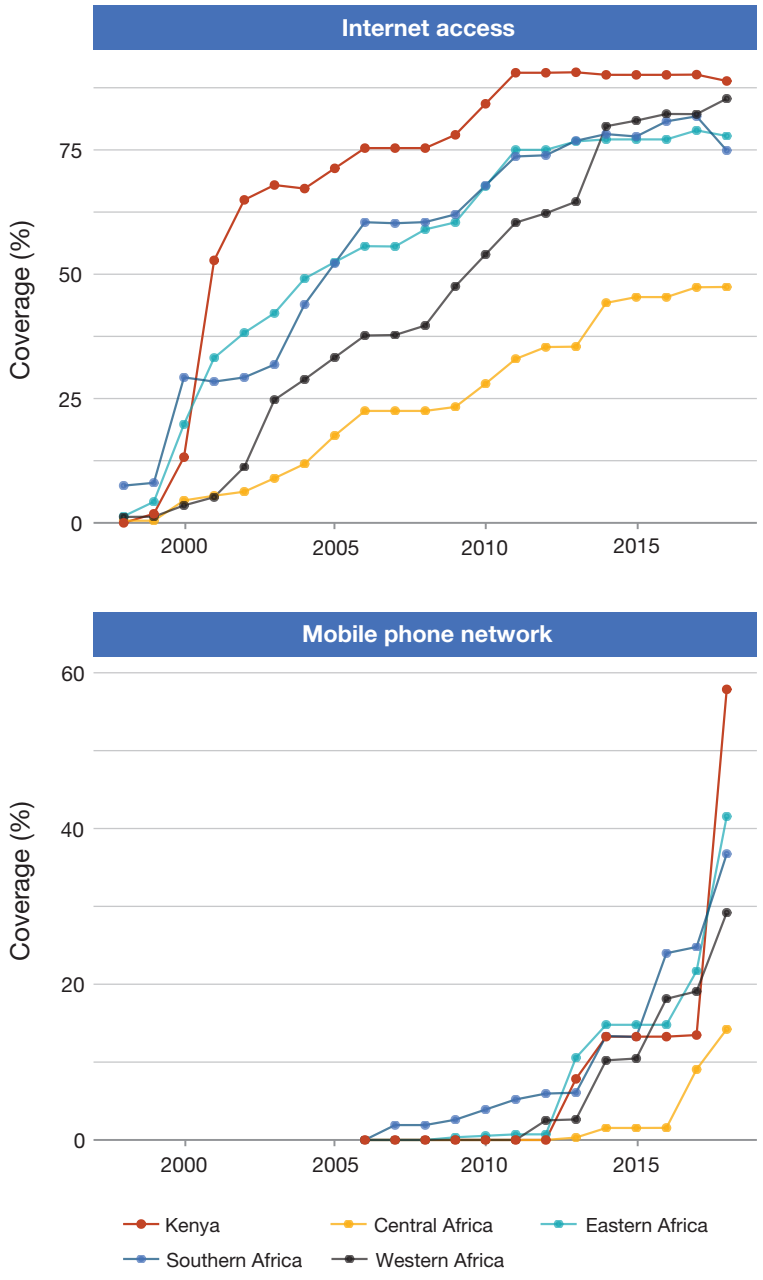
Explaining Kenya's success in the digital space

Unique features of Kenya's digital ecosystem

Kenya represents one of the few countries in Africa that has made significant strides in the deployment and use of digital innovations. The country is ranked third in Africa and fifth in the Middle East and Africa region in its startup ecosystem (StartupBlink 2022). The country's success in the digital space owes largely to its reliable internet/broadband connectivity and its high mobile/internet subscription rate, combined with well-positioned incubation and accelerator centers, a thriving innovative and entrepreneurial environment, a (relatively) robust digital marketplace, and a conducive business environment that encourages active private sector participation (Drouillard 2017; Osiakwan 2017).

Reliable internet connectivity and near universal mobile subscription. Kenya has among the fastest and most reliable internet connectivity in Africa, mainly because of strategic public and private investment in internet infrastructure such as the national fiber optic backbone infrastructure (Osiakwan 2017; UNDP 2022). As a result, Kenya's internet access and use subscription has been increasing significantly over the past decade. By December 2021,

FIGURE 18.1 Connectivity in Kenya and sub-Saharan African regions



Source: Authors using GSMA (2022) data.

data/internet subscriptions stood at 46.3 million, of which 28.4 million were mobile broadband subscriptions (CA 2021). Kenya's broadband infrastructure, in particular, has helped increase network reach and bandwidth and dramatically reduce the cost of data/internet—essential elements to scale up digital innovations. Kenya's growth in broadband and internet connectivity remains phenomenal when compared with other countries/regions in sub-Saharan Africa (Figure 18.1). The current broadband strategy further aims "to transform Kenya into a globally competitive knowledge-based society enabled by affordable, secure and fast broadband connectivity" (GOK 2021).

A thriving innovative and entrepreneurial environment. Kenya is also taking exemplary steps to address the human capital constraints that otherwise impede the creation and use of digital innovations in most African countries, by building robust training, incubation, and accelerator centers that provide the skills needed for the digital economy. Kenya's start-up sector is one of the most vigorous on the continent, dubbed "Silicon Savannah" because of the increase in start-ups of technology-based firms in recent decades. By 2020, more than 30 start-up incubators and accelerators were operational in greater Nairobi alone, each working with several start-up firms (Hellen 2021). Most of the applications that are providing digital solutions in the areas of agriculture and the food system (indicated in Appendix 18.1) are a result of the country's openness to innovative entrepreneurs and to harnessing the potential of disruptive technological innovations. The country's success and its reputation as a vibrant hub for tech entrepreneurs has also attracted multinational tech firms such as IBM and Microsoft to open operations in Kenya and create a program to train aspiring innovators (USAID 2020).

Relatively robust digital marketplace. Digital business, an essential element of digital transformation, is relatively developed in Kenya, in both reach and breadth. In 2017, about 39 percent of private enterprises in Kenya were engaged in e-commerce, and mobile transactions alone represented KSh 3.2 trillion. Over 82 percent of smallholder farmers in Kenya use mobile-based financial transactions, although only 15 percent is for agriculture-related purposes (Parlasca, Johnen, and Qaim 2022). There is also a strong tendency toward digitizing government services: e-government plays a crucial role both as orchestrator of the digital ecosystem and in signaling the preferred direction of the country to the private sector and other stakeholders (Schuppan 2009; Kenya, Ministry of Information, Communications, and Technology 2019).

Business-friendly environment. An enabling business environment that supports active private sector participation is another crucial element driving

digital innovation in Kenya. The government allows private firms and other stakeholders to test digital solutions under easy operation and registration procedures, and with guaranteed intellectual property rights. The business environment in Kenya also encourages a wide range of business models, including government funding, recognizing the public good characteristics of some of the digital innovations. For instance, KAOP, developed by KALRO, is a publicly funded digital innovation that provides information on weather as well as pest and disease forecasts. Meanwhile, iCow and DigiFarm are supported by a private mobile network operator (Safaricom) that is actively exploring/seeking more sustainable business models (Birner, Daum, and Pray 2021).

Policies and regulatory systems to support digital innovations

Kenya's success in digital innovation is also partly driven by adaptive and outcome-based policies and regulations. Policymakers and regulators in the country seem to have a relatively strong preference for responsive regulation that set rules ex-post as services and their providers evolve, as opposed to prescriptive ex-ante regulation. An example here is the "test and learn" approach that the country followed when M-Pesa was launched (Ndung'u 2019). Kenya's 2019 Digital Economy Blueprint also clearly states that regulations need to focus on the service delivered to consumers rather than on the type of company or technology that delivers the services—a regime that encourages companies to experiment and innovate in a multitude of products and services.

The need for strong coordination and collaboration among regulatory bodies is another key lesson other African countries can learn from Kenya. Key government bodies (the Central Bank, the Communications Authority, and the Competition Authority) have coordinated on regulatory issues related to digital innovations from the initial stages of digital transformation. This has allowed a coordinated set of regulatory actions to emerge across regulators over time (Ndung'u 2019; UNDP 2022).

Digital policies and regulation in Kenya also strive to support digital agriculture, and digital solutions are identified as a strong enabler in achieving the food security pillar of the country's Big Four Agenda (FAO 2021). Several policies and high-level commitments have also been put in place to ensure that poor smallholder households, and especially women, enjoy the benefits of digitalization. These policies and commitments have eased the growth and development of different business models that address the main constraints in meeting some of the key development outcomes of eradicating hunger and poverty.

Success stories

Some of the key successes in Kenya's digital space hail from applications that deliver financial services. One case is M-Pesa, which is arguably the most successful digital innovation in sub-Saharan Africa. Although its use is widespread, it is expected to be particularly beneficial for smallholder farmers, who usually lack access to financial services. Studies from Kenya have shown that these digital innovations are associated with increases in household welfare (Kikulwe, Fischer, and Qaim 2014; Suri and Jack 2016; Parlasca, Mußhoff, and Qaim 2020; Hartmann, Nduru, and Dannenberg 2021). These digital financial services have also been critical in protecting and cushioning households from income and health shocks through increased remittances (Jack and Suri 2014). These impacts have been shown to be more pronounced for women and women-headed households (Suri and Jack 2016). Related to M-Pesa is the use of M-Shwari, a mobile bank account innovation that offers credit and saving services in collaboration with M-Pesa (Bharadwaj and Suri 2020).

Despite the potential of digital financial services like M-Pesa and M-Shwari to revolutionize smallholder agriculture, some of these services are greatly underused by farmers for agricultural purposes, limiting their transformative impact. While the use of mobile money services is high (82 percent) among farmers in Kenya, only about 15 percent of farmers use such services for agriculture-related purposes and less than 1 percent engage in mobile banking and loans (Parlasca, Johnen, and Qaim 2022).

Beyond these digital financial innovations, success stories also emerge from more production-oriented digital innovations, such as DigiCow, iCow, and M-Kilimo. DigiCow and iCow offer extension and advisory services to pastoralists. iCow is a globally known digital and extension tool for livestock development (Daum at al. 2022). It offers both simple and smart services to pastoralists, including but not limited to feeding, gestation, disease control, and milking information, as well as other agronomic, forestry, and ecological information. This digital tool has been shown to induce better disease and hygiene management practices with positive implications for yields and animal health (Daum et al. 2022). Another success story from Kenya's digital space is KAZNET, a digital platform that relaxes some of the constraints associated with conventional data collection methods and assists in the collection of high-frequency data in remote pastoral regions (Chelanga et al. 2022). The KAZNET micro-tasking platform was used to crowdsource data from various livestock markets under COVID-19 to track the effect of the pandemic on livestock development (Graham et al. 2021).

Is Kenya's progress in digital innovation sufficiently transformative?

Although our review and assessment of Kenya's progress in digital agricultural innovation offer reasons to be optimistic about its reach and impact, we find that the achievements thus far are still largely unknown and not necessarily "transformative" in the way the term is conventionally understood in the agriculture and food system space. Many agriculture-focused digital innovations remain at a pilot stage, such that there seems to be a significant and persistent disconnect between piloting and scaling-up (see, for example, World Bank 2016; CTA 2019; Fabregas et al. 2019; Steinke et al. 2020).Thus, Kenya may not yet be reaping the full potential of digital innovation. This signals a need for additional investment to address critical infrastructural and human capital constraints that are impeding the creation and use of digital tools, particularly among Kenya's underserved smallholders. We examine these issues in greater detail below.

Disconnect between pilots and scale-ups

Despite the remarkable success Kenya has achieved in terms of nurturing digital innovations, there is a long way to go to achieve widespread scale-up and learning from these experiments. Although digital innovations lend themselves readily to rigorous evaluation, most studies to date have focused on identifying the impacts of just a few successful digital innovations. Most such evaluations have looked at the high-profile cases, such as M-Pesa and its associated services (for example, Suri and Jack 2016; Suri et al. 2021). Very few studies systematically and rigorously examine impacts on smallholder farmers and other market actors, leading to a lack of in-depth understanding on how digital innovations are improving the functioning and performance of input markets, value chains, or innovation networks in the agriculture and food system. This shortage of nuanced evidence and experience from both successful and unsuccessful scaling efforts impedes learning and makes it difficult for farmers and other actors to differentiate between what has truly worked and what has not.

Bottlenecks to widespread and meaningful scale-up

This limited evidence on widespread use and scale-up may point to a larger challenge: the simple fact that some of these innovations may not be scalable. However, there are also more complex supply- and demand-side constraints to scaling that may warrant greater attention. Below, we briefly describe these major constraints.

SUPPLY-SIDE CONSTRAINTS TO SCALING

Efforts to scale up digital innovations that can fundamentally transform Kenyan agriculture likely require considerable public investment in infrastructure and talent—investments that often have public goods attributes and thus can be implemented only by governments. At the same time, the scale-up of these innovations requires a certain degree of public sector withdrawal from the market so that input and commodity suppliers can compete on a level playing field and leverage digital innovations to reduce their costs and secure competitive advantages. The Kenyan digital innovation landscape faces *insufficient investment from both public and private sector sources*. Private investment in digital agriculture-related technologies lags because of the initial fixed costs required, the non-appropriability of added value from many information-based services, and the long lag times to profitability even with a credible business model (Fabregas et al. 2019). Yet public resources are scarce in Kenya, subject to fierce competition over their distribution and use, and tied to election cycles and other short-term outlooks. Overall, this means that the government is not always positioned to make the needed long-term investments in soft and hard infrastructure to support digital innovation. Meanwhile, only a few private entrepreneurs and investors have the financial capacity or appetite to invest in digital tools to support what are often perceived as high-risk, low-return activities in the agriculture sector. Although external donors—bilateral and multilateral funding agencies such as the World Bank—continue to support investments in digital technologies in Kenya, their impacts on smallholder agriculture remain marginal.

Second, some of the rapid progress in digital innovations in Kenya has not been accompanied by parallel progress in agricultural systems themselves. This relates to the *asynchronous pace of change*. In effect, the pace at which digital innovations bring solutions to agricultural activities and markets is not being matched by changes in the rate of institutional transformation that is needed to support and sustain these digital technologies (for example, CTA 2019). This is particularly the case in terms of delivering agricultural services and transactions, which continue to operate in environments characterized by isolation, limited scale, and risk (Benami and Carter 2021).

Third, many digital tools and innovations in Kenya and Africa fail to embed within existing institutional infrastructure. Digital innovations and technologies can thrive if they are integrated within a conducive business environment and regulatory framework. Kenya, like many countries in Africa, still *lacks comprehensive and dynamic digitalization policies* to support digital innovation in the agriculture sector.

Finally, most companies investing in agriculture-focused digital technologies in Kenya are still *struggling to develop sustainable business models,* partly because of the incipient nature of market development (that is, lower demand at early stages owing to some of the factors we discuss below). This limits the reach and scale-up of digital tools that can support smallholder agriculture. Several digital innovations developed through donor funding are struggling to ensure a healthy balance between generating impact and financially sustaining themselves.

DEMAND-SIDE CONSTRAINTS TO SCALING

The rapid emergence of digital tools in Kenya—and Africa—requires an appropriate response, including research on context-specific needs and cost-benefit analysis. However, many digital innovations enter the market without proper contextualized demand analysis. In the absence of such knowledge and the related infrastructure, new digital tools end up being alien to farmers and hence fail to attract demand. Indeed, some evaluations and willingness-to-pay analyses show that smallholders in low- and middle-income countries (including Kenya) do not want to pay the full cost for some of these innovations for several reasons, including lack of trust and the non-excludability of the information and services (shareability) most digital solutions provide (see, for example, Fabregas, Kremer, and Schilbach 2019; Cole and Fernando 2021).

Using digital tools and innovations usually requires some level of literacy and numeracy, skillsets smallholder farmers in Kenya often lack. Thus, the accessibility and usability of digital innovations in Kenya and Africa deserve critical attention. In addition, low digital literacy appears to be an important factor limiting wider usage and scale-up of digital innovations (CTA 2019). For example, 28 percent of digital technology enterprises report consumer-level digital literacy as an important barrier to the adoption and use of digital innovations in Africa (ibid.). Besides this, user confidence in digital tools is another important factor related to the scale-up of digital innovations. Smallholders are more likely to embrace digital innovations if they can access reliable and trustworthy services and information.

Finally, digital innovations in Kenya and many parts of Africa are not sufficiently inclusive. Entrepreneurs and companies are most likely to target easy-to-reach markets and customers (CTA 2019), thus some digital tools may not benefit marginalized smallholders. Indeed, many argue that differential access to digital innovations and associated complementary infrastructure is generating a digital divide in Africa. For example, less than 40 percent of smallholder households in Africa have access to the internet—while this increases with farm size (Mehrabi et al. 2021). Similarly, women have relatively lower

access to the internet and mobile phones, triggering an important gender gap and digital divide.

Overall, although Kenya has made significant strides in the adoption of digital innovations, this progress has not been sufficiently transformative, especially in the agriculture sector. The most transformative digital innovations in Kenya have been those that facilitate financial transactions (for example, M-Pesa and M-Shwari), which have achieved significant scale. However, these innovations are still not widely used for agricultural purposes. As indicated above, the use of mobile financial services by farmers for agriculture-related purposes remains limited, and as a result such services have not yet had a transformative impact on smallholder farming (Parlasca et al. 2022). Smallholder farmers usually trade in small quantities and mostly on a face-to-face basis with input suppliers, market agents, and consumers. They prefer cash, given that mobile money payments entail a fee (Parlasca et al. 2022). This reality may not be unique to these digital platforms, as farmers rarely make use of credit services in sub-Saharan Africa (Adjognon, Liverpool-Tasie, and Reardon 2017).

What will it take to make Kenya's digital innovations transformative in agriculture?

Realizing the full potential of digital innovations in Kenya requires the scaling up of current efforts and momentum related to the development and use of wide-ranging digital solutions. An immediate step in this direction entails addressing the *human capital* constraints that usually impede both the creation and the use of digital tools (Birner, Daum, and Pray 2020; Kim et al. 2020; Jellason, Robinson, and Ogbaga 2021; Malabo Montpellier Panel 2019). Because of these human capital constraints, most existing digital agricultural innovations in Kenya offer a limited range of solutions. Efforts are evolving to support incubators and start-ups, which may help advance ICT skills. In particular, there is a need to scale up support to innovation hubs and IT incubators and other local tech networks to embrace the agriculture sector and target smallholders. These human capital investments should be accompanied by efforts to familiarize and train users of digital innovations, especially farmers, who may have limited digital literacy. While investment in the digital literacy of users is important, digital innovations should also be adapted to the realities on the ground (Trendov, Varas, and Zeng 2019; Daum et al. 2022).

Second, the digital infrastructural space in Kenya requires greater public and private investment in *complementary infrastructure,* which refers to the amenities essential to scale digital solutions. While infrastructure such as internet connectivity, mobile network coverage, and electricity coverage

continue to increase, further investments and expansion to rural farm households can improve the usability and accessibility of digital innovations for smallholder farmers. Such infrastructure is a public good and hence this requires the government to be the first mover.

Third, realizing the full potential of digital innovations requires sustainable delivery of services, which in turn requires *sustainable business models* for private entrepreneurs. Although digital innovations providing financial services have sustainable operations, most digital solutions targeting smallholder farmers in Kenya rely heavily on public—particularly *donor*—funding. Although donor funding can be instrumental at the pilot stage, these funding agencies need to quickly push digital providers toward viable business models to ensure sustainability.

Finally, Kenya needs to maintain *dynamic policies and smart regulations* that can further spur digital innovations and ensure equitable distribution of digital dividends. This is partly because regular updating and adjustment of digital polices is a necessary condition to address the dynamic needs of digital ecosystems.

What can Africa learn from Kenya in digitalizing agriculture?

Kenya offers important lessons for other African countries that are aspiring to adopt and scale digital innovations to facilitate agricultural transformation. These lessons can be grouped into four major avenues. First, tapping the potential of digital innovations requires significant infrastructural investments. Kenya has made significant strides in the digital space in terms of improving mobile/internet infrastructure. Many other African countries have weak internet infrastructure and differential access to the internet and mobile phones across communities and households, and this is triggering variants of the digital divide (for example, Mehrabi et al. 2021). Such countries need to revitalize investments and policies to ensure the digital inclusion of marginalized households and communities.

Second, Kenya's digital infrastructure is supported by its relatively advanced digitalization policies, which aim "to transform Kenya into a globally competitive knowledge-based society enabled by affordable, secure and fast broadband connectivity" (GOK 2021). Many countries in Africa still lack comprehensive and dynamic digitalization policies and Kenya thus offers an important lesson here, especially with regard to its preference for more adaptive/responsive regulations to digital innovations as opposed to prescriptive regimes. Kenya's

experience in ensuring and facilitating strong coordination and collaboration among regulatory bodies is also an important lesson for other African countries, some of which lack proper regulatory frameworks.

Third, Kenya's experience in addressing the human capital constraints that impede the creation and use of digital innovations, through building robust incubation and accelerator centers, is also an important lesson. Finally, Kenya's business environment also has lessons to pass on to other African countries in terms of supporting and attracting private sector participation in digital innovations. Kenya's business environment encourages experimentation in digital solutions, with its easy registration procedures and guaranteed intellectual property rights.

However, we note that Kenya's progress is still not sufficiently transformative, especially with respect to agriculture-focused digital innovations. Replicating some of the most transformative digital innovations in Kenya, mainly those that facilitate financial transactions (for example, M-Pesa and M-Shwari), in smallholder agriculture is an immediate next step. Future efforts should also be accompanied by systematic assessments of both successes and failures at different stages of the piloting and scaling up of digital solutions.

Appendix 18.1 Typology of agriculture-oriented digital tools

TABLE A18.1 Typology of agriculture-oriented digital tools in Kenya

Typology of digital tool	Name of tool	Description	Key functions
Agricultural extension and advisory services	iCow	iCow is an app that aims to reduce cow mortality rates and educate farmers on proper agricultural practices. It is a mobile-based agricultural platform designed to improve smallholder farmer productivity and profitability.	Agricultural extension Market information
	DigiCow	DigiCow is a mobile app designed to use data and feedback production, financial reports, and breeding and health reports. In addition, it has a digital loan facility meant to offer credit to farmers.	Agricultural extension Data-driven decisions
	Digital Green	Digital Green seeks to help the poor lift themselves out of poverty by empowering them through digital technology and grassroots partnerships.	Video extension services
	Kuza Biashara	Kuza Biashara operates a digital micro learning and community platform and aims to improve food security and revolutionize resilience through empowering communities to learn, connect, and grow to scale.	Video extension services
	iShamba	iShamba is a call center of agricultural experts; farmers can send an SMS or call to ask an expert for instant help. iShamba helps farmers improve their farms and get better yields.	Agricultural extension Farming information
	Viazi Soko	Viazi Soko is a platform to facilitate online marketing of potato-related products and services. It was developed with the aim of helping address various challenges facing potato farmers and other stakeholders.	Assistance to market potatoes
	Budget Mkononi	Budget Mkononi is an interactive web-based budgeting tool designed to help young and inexperienced farmers identify the basic costs and elements required to set up and run their farming enterprise. It also has a farming guide on each commodity listed, with further information on how to plant, manage, harvest, and finance an agribusiness.	Information to help manage finances
Weather information and services	KALRO KAOP	The KAOP app helps farmers monitor weather through their mobile phones. KAOP generates real-time and location-specific agro-advisories for farmers and other stakeholders to enable them to make more informed farming decisions.	Information on weather
	CLIMARK MyAnga	MyAnga is part of a wider project called CLIMARK whose aim is to disseminate actionable weather advisories to residents of Marsabit and Isiolo counties. The project was set up to design and deploy a blended weather information management system.	Weather advisories
	SunCulture	SunCulture aims to solve the energy challenges of smallholder farmers, using off-grid solar technology to provide farmers with reliable access to water, irrigation, lighting, and mobile charging, all with a single system.	Solar solutions

Continued

Typology of digital tool	Name of tool	Description	Key functions
Market information systems and linkages	Kenya Agricultural Commodity Exchange (KACE)	KACE is primarily an information service to enhance price discovery as well as a spot exchange. It facilitates linkage between buyers and sellers, exporters and importers of agricultural commodities in trade. It provides farmers and market intermediaries relevant information about markets, and other services to enhance their bargaining power and competitiveness in the marketplace.	Information on exchange rates
	M-Kilimo	M-Kilimo is a mobile platform that help farmers, livestock keepers, and fishers to obtain market information using mobile phones.	Disseminates market information
	Farmshine	Farmshine connects farmers with information, suppliers, and service providers.	Linking local farmers to global markets
	Herdy Fresh	Herdy Fresh works with local farmers, upcoming brands, and stores to bring consumers a wide selection of high-quality products and services at great value to ease the burden of city living.	Linking local farmers to consumers, especially in urban areas
	Kitchen Soko	Kitchen Soko links consumers directly to the source by letting them know their farmer or baker or butcher to ensure accountability. With Kitchen Soko, one can shop directly from the farmer and producer.	Direct link from famer to consumer enhances traceability
	Mifugo.trade	Mifugo.trade facilitates livestock trade through an online livestock and livestock products exchange that directly connects livestock producers to buyers.	Linking sellers and buyers of livestock
	Selina Wamucii	Selina Wamucii is a global sourcing platform for food and agricultural produce, incorporating the world's producers, cooperatives, processors, and farmers. It is a market access solution for farmers and integrates them with cooperatives, producer organizations, agro-processors, and other organizations.	Linking global farmers to global customers
	Taimba	Taimba is a mobile-based cashless platform that connects farmers to retailers such as small-scale traders "mama mbogas," mini-markets, and restaurants.	Connecting farmers to retailers
	TruTrade	TruTrade is a social enterprise providing smallholder farmers with a reliable route to market and fair prices for their produce.	Linking farmers to markets
	Tulaa	Tulaa connects farmers with suppliers of fertilizer, seeds, and finance.	Linking farmers to farm inputs
	Twiga Foods	Twiga simplifies the supply chain between fresh food producers, manufacturers, and retailers through a business-to-business e-commerce platform.	Linking food value chain supplies and consumers
	Farm to Market Alliance	The Farm to Market Alliance empowers smallholders to become reliable market players through access to four integrated pathways: predictable markets, affordable finance, technologies and quality inputs, and handling and storage solutions.	Linking farmers to markets
	iProcure	iProcure is a mobile app specifically designed to support wholesale suppliers. Its main purpose is to make it quick and easy for customers to place their orders.	Linking wholesale suppliers and consumers
	Jumia	Jumia is an online retailer. It mostly links sellers and buyers. This includes the agricultural market.	Linking buyers and sellers
	Farmers Pride	Farmers Pride is a mobile app that connects organic farmers to customers. This app provides customers with 100 percent organic products.	Connecting organic farmers to consumers

Continued

Typology of digital tool	Name of tool	Description	Key functions
Digital financial services (intermediation and payment systems)	M-Pesa	M-Pesa is a mobile phone-based money transfer service, payments, and microfinancing service, launched in 2007 by Vodafone and Safaricom, the largest mobile network operator in Kenya.	Transactions
	M-Shwari	M-Shwari is a savings and loan service that enables M-PESA customers to save and access credit.	Saving and overdrafts
	Dodore	Dodore provides a fintech solution that ensures financial flow between farmers, markets, agrovets/dealers, and suppliers. The agri-wallet also offers loans and savings options for farmers.	Financial management
	DigiFarm	DigiFarm offers smallholder farmers access to a suite of information and financial services, including discounted products, customized information on farming best practices, and access to credit and other financial facilities.	Information on financial facilities
Supply chain coordination (agricultural inputs and services)	Smart Cow	Smart Cow is a dairy management software app. It helps keep records of livestock and monitor daily milk production for each individual cow. It also keeps a well-organized record of insemination and breeding and all health records for individual cows and groups.	Dairy management system
	Viazi Soko	Viazi Soko is a platform to facilitate online marketing of potato-related products and services. It was developed with the aim of helping address various challenges facing potato farmers and other stakeholders.	Assistance to market potatoes
	E-Tinga	Tinga Rental Store is a platform that helps in accessing superior agricultural machinery services through a rental platform for a predetermined time.	Information on farm machinery for rental
	FarmIT	FarmIT facilitates real-time tracking of harvests.	Tracking of harvests
	MTela	MTela is a shop management app for agricultural input retailers. It helps with their sales and inventory management.	Financial management
	M-shamba	M-shamba supports digital learning on agronomy, regenerative agriculture, and food safety for farmers through its Interactive Voice Response service, USSD, and interactive SMS.	Using data to inform on demand for and supply of output
	Apollo Agriculture	Apollo bundles everything a farmer needs: financing, inputs, advice, insurance, and market access, when possible. It uses satellite data and machine learning to enable better credit decisions. It also uses automated operations to keep costs low and processes scalable.	Farm management decisions and automated operations
Data and crowdsourcing services	KAZNET	KAZNET is an android app developed to solve the need for accurate and timely market information from participants in remote areas.	Collecting market information
	Nuru	Nuru deploys artificial intelligence and Google's TensorFlow technology to improve surveillance and management of crop diseases.	Identifying cassava diseases

Source: Authors using multiple sources.

Note: This is not an exhaustive list of digital tools operating in Kenya.

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