INTERNATIONAL DEVELOPMENT IN FOCUS

Scaling Up Disruptive Agricultural Technologies in Africa

Jeehye Kim, Parmesh Shah, Joanne Catherine Gaskell, Ashesh Prasann, and Akanksha Luthra

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Foreword

Boosting the productivity, profitability, and sustainability of the agri-food system in Sub-Saharan Africa is essential for the region's economic growth, poverty reduction, food security and nutrition, and employment. This is especially true against the backdrop of rising food demand, which is estimated to increase by at least 20 percent globally over the next 15 years, with the largest rise projected in Sub-Saharan Africa. The world needs a food system that can feed every person, every day, everywhere with a nutritious and affordable diet, delivered in a climate-smart, sustainable way.

To achieve this goal, we can leverage technology as a tool to be more productive and efficient in the way we grow and build the resilience of the agri-food system. The advancement of technology has provided us a historic opportunity to transform the system. Disruptive agricultural technologies (DATs) have the potential to significantly reduce the costs of linking sellers and buyers; reduce inequalities in access to information, knowledge, technologies, and markets; help farmers make more precise decisions on resource management by providing, processing, and analyzing an increasing amount of data faster; and potentially reduce scale economies in agriculture, thereby making small-scale producers more competitive—in a way, leveling the playing field. The success of DATs is a function of policies and regulations that foster growth in the agri-food system, well-functioning markets, and thriving businesses that make food more available in rural and urban areas.

In pursuit of advancing the growth of disruptive agricultural technologies and thus the agri-food system, we are pleased to present the World Bank Group's *Scaling Up Disruptive Agricultural Technologies in Africa*, the first in a series analytical studies and operations. This book aims to further the state of knowledge about the emerging trend of disruptive agricultural technologies in Africa, with a focus on supply-side dynamics. This book will also contribute to regional integration through knowledge sharing and collective policies and investments to transform agriculture. The analysis in this book is based on a novel, non-exhaustive database of DATs in Sub-Saharan Africa, as well as an ecosystem analysis of Kenya and Nigeria. The purpose of the ecosystem analysis is to understand the successes, challenges, and opportunities both countries faced when fostering a conducive innovation ecosystem for scaling up DATs.

This book is designed to support practitioners, decision-makers, and development partners who work at the intersection of agriculture and technology to promote the advancement of the agri-food system. We hope that this book will be a practical guide for understanding the current landscape and trends and for implementing appropriate interventions by each of the development partners as well as the World Bank, thus promoting the growth and scaling up of DATs in Sub-Saharan Africa.

This book is the result of an endeavor by the Disruptive Agricultural Technology (DAT) Africa team, based within the Agriculture and Food Global Practice of the World Bank, with significant contributions from other relevant Global Practices and external partners and experts. This effort was funded by the Korea–World Bank Partnership Facility. We are grateful for these contributions and look forward to continuing work that assists countries in reducing poverty and increasing shared prosperity.

Simeon Kacou Ehui
Regional Director for Africa,
Sustainable Development
World Bank Group

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As a part of the analytical work, the team organized the Disruptive Agricultural Technology (DAT) Innovation Knowledge and Challenge Conference in Kenya in April 2019. The team extends its gratitude to the co-organizers of the conference in Kenya: KWPF and the Ministry of Agriculture, Livestock, Fisheries and Irrigation (MoALFI). This event would not have been possible without the strong support of Mwangi Kiunjuri, then Agriculture Cabinet Secretary, and Hamadi Boga, Principal Secretary at MoALFI. The team recognizes the constant support from Governor Muthomi Njuki, Chair of the Agriculture Committee Council of Governors, and Mary Nzomo, Chair of County Executive Committee for Agriculture, for the success of the DAT initiative.

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Executive Summary

INTRODUCTION

Sub-Saharan Africa's agri-food system is critical for the region's economic growth, poverty reduction, food security and nutrition, and employment. Agriculture contributes about 15 percent of gross domestic product (GDP) growth in Sub-Saharan Africa. Evidence shows that a 1 percent increase in agricultural GDP reduces poverty, on average, by more than 1 percent, whereas a 1 percent increase in industry or services GDP reduces poverty by less than one-half of 1 percent. Agri-food systems are also important for food security, given that one-quarter of the continent's population is undernourished. By 2030, the continent will have half a billion more people to feed. Finally, agriculture is central to African job growth. More than 330 million people will enter the African labor force over the next 20 years, and the agri-food system could potentially absorb about 70 percent of these new entrants. The agri-food system can—and needs to—play a key role in accelerating growth, ending poverty and hunger, and contributing to job creation in Sub-Saharan Africa.

The agri-food system is characterized by several challenges that are impeding its ability to achieve a higher growth trajectory and to generate greater agri-food outcomes. First, the agri-food system is large and complex, with many dispersed actors. Africa has 300 million rural inhabitants, many of who are farmers based in remote areas without access to the emerging trillion dollar agri-food market. Second, resource use and market access are marked by vast inefficiencies. Smallholder farmers struggle to connect with input suppliers—whether for seed, machinery, fertilizer, finance, or advisory services—and with farms and farm enterprises. Food production is risky, in part because of limited information about weather patterns, soil characteristics, future market demand, and other variables. With limited information, farmers' decisions are based on intuition, and thus are often less efficient than they could be. Third, Africa's food system suffers from inequalities in access to technologies, information, and markets. These inequalities manifest in the form of marginalized groups, such as low-skilled farmers, both men and women, based in rural areas with limited connectivity, who traditionally have lower access to information and markets.

Disruptive technologies have the potential to help address many of the above-noted challenges. Disruptive technologies in agriculture consist of digital and technical innovations that enable farmers and agribusiness entrepreneurs to leapfrog current methods to increase their productivity, efficiency, and competitiveness, thereby facilitating access to markets, improving nutritional outcomes, and enhancing resilience to climate change. Agri-tech solutions range from mobile phone apps to solar applications, portable agriculture devices, and bio-fortified foods. Disruptive agricultural technologies (DATs) differ from other agri-technology solutions in that they empower farmers by accelerating agri-food outcomes three- to fivefold or by circumventing the conventions of the value chain to achieve the same or better results—but with a more efficient agri-food outcome.

DATs, by addressing the most pressing agricultural challenges, will contribute to improving agricultural outcomes. First, DATs help farmers by reducing the costs of linking various actors in the agri-food system both within and across countries through providing, processing, and analyzing an increasing amount of data faster. Second, DATs help farmers make more precise decisions about resource management through accurate, timely, and location-specific price, weather, and agronomic data and information, which are becoming increasingly important in the context of climate change. Third, DATs can make smallholders and especially marginalized farmers more competitive by leveling the playing field. Even in poorly connected rural contexts, or with marginalized groups that have lower access to information and markets, sophisticated off-line digital agricultural technologies can provide opportunities to help poor and even illiterate farmers.[1] In short, DATs are overturning the sector status quo, providing an innovative approach to addressing system-wide challenges (see table ES.1 for some illustrative examples).

TABLE ES.1 Agricultural challenges and relevant examples of DATs in Africa

CHALLENGE FRAMEWORK	AGRICULTURAL CHALLENGES	STANDARD AGRICULTURAL SOLUTIONS	DAT SOLUTIONS	ILLUSTRATIVE DAT EXAMPLES
Agricultural productivity	Insufficient advisory and climate-smart services	Producer organizations, extension agents, radio, TV	Agricultural extension and advisory services delivered through videos and platforms linking experts	Digital Green in Ethiopia; Precision Agriculture for Development in Kenya
	Limited access to inputs (tractors) for land preparation	Manual, animal-aided, mechanized	Digitally enabled tractor-hiring services	Hello Tractor in Nigeria
	No systematic pest and disease management	Observe and respond	Real-time alert systems	Waterwatch Cooperative in Kenya
Market links	Poor market access	Farmer cooperatives, intermediaries	Digital platforms for finding buyers and linking buyers and sellers	Tulaa in Kenya; Maano in Zambia; Farmshine in Kenya; Zowasel in Nigeria
Farmer financial inclusion	Insufficient or unfair access to credit and financial products	Moneylenders, family and friends	Platforms for input credit, e-wallets, and insurance products	Agri-wallet in Kenya
Data analytics and agricultural intelligence	No or inadequate access to data for informed decision-making	Intuition based on observation, no solution	Portable soil testers, satellite images, remote sensing	Agrocares, based in the Netherlands and operating in Kenya; UjuziKilimo in Kenya
Energy for agriculture	Poor irrigation infrastructure	Rainfed, manual, gravity-aided	Solar-powered irrigation pumps	SunCulture in Kenya

Source: World Bank.
Note: DATs = disruptive agricultural technologies.

Nowhere is the potential of disruptive technologies in agriculture more promising than in Sub-Saharan Africa, where agriculture employs nearly 70 percent of the region's entire population. Recognizing the potential of DATs to accelerate the efficiency, equity, and sustainability of agri-food systems, African governments are seeking to understand the nature of these technologies, their impact, and their constraints. The key questions are, How are DATs affecting agri-food system outcomes? What does it take to create and foster ecosystems conducive to scaling up DATs? How can governments and partners, such as the World Bank, help local entrepreneurs, innovators, youth, and agribusinesses confront institutional challenges in the industry? To answer these questions, it is important to study the supply-side dynamics of DATs.

This study—including a pilot intervention in Kenya—aims to further the state of knowledge about the emerging trend of DATs in Africa, with a focus on supply-side dynamics. Three activities contributed to the book's findings. The first activity was a stocktaking analysis to assess the numbers, scope, trends, and characteristics of scalable disruptive technology innovators in agriculture in Africa. The foundation of the analysis was a database that focused explicitly on the scale of existing DAT operations, and thus all 194 DATs in the database are identified as scalable DATs. The second activity was a comparative case study of Africa's two most successful DAT ecosystems in Kenya and Nigeria, which together account for half of Sub-Saharan Africa's active DATs. The third activity was the Innovation, Knowledge, and Challenge Conference in Nairobi, Kenya, that brought together more than 300 key stakeholders from large technology companies, agribusiness companies, and public agencies; government representatives (such as governors and country agriculture ministers); experts from research and academic institutions; representatives from financial institutions, foundations, and donors; and venture capitalists. The conference, aimed at jump-starting Kenya's DAT innovation ecosystem through knowledge sharing, culminated in the selection of 14 DAT innovators to participate in the new One Million Farmer Initiative platform that will leverage the World Bank's existing engagements in agriculture in Kenya to scale up the adoption and development of DATs.[2]

This study is the first in a series of analytical studies and operations on disruptive agricultural technology in Sub-Saharan Africa that will contribute to regional integration through knowledge sharing and collective policies and investments to transform agriculture. If governments and development partners come together to drive this agenda in Sub-Saharan Africa, there is potential to create multiplier effects through trade, market access, and a regional innovation ecosystem. This study also forms part of the World Bank Group's support for the African Union's Digital Moonshot for Africa, which aims to digitally enable every African individual, business, and government by 2030. This study also aligns with the Digital Economy for Africa Initiative by the Digital Development team at the World Bank. Aligned with the World Bank Group's overall strategy, this study brings a unique, distinctive, and complementary perspective. The infoDev team at the World Bank supports early phases of start-ups, whereas International Finance Corporation (IFC) investments support later stages of start-ups' growth. This study, as well as future studies and operational work, will focus on DAT start-ups that are in the intermediate phases, that is, in between infoDev and IFC, the critical stages when DATs have an established service or product and are on a growth trajectory.

The stocktaking analysis in this book is based on a novel, nonexhaustive database of scalable DATs in Sub-Saharan Africa that has been curated through

secondary research. This database of 194 DATs forms the basis of the landscape analysis, given the selected DATs' proven products and growth potential. Therefore, this database is a unique snapshot of a dynamic sector and is not meant to be exhaustive. The data were collected from a variety of secondary research sources (including company profile sources such as Tracxn, Pitchbook, Crunchbase, Google searches, literature reviews, and so on). A total of 434 for-profit and nonprofit organizations were reviewed. From the original 434, 194 organizations were identified as scalable DATs if they met the inclusion criteria. Because the database primarily comes from company profile sources and these sources focus on for-profit companies, more than 95 percent of the identified DATs in the database are for-profit organizations with operations in Sub-Saharan Africa.

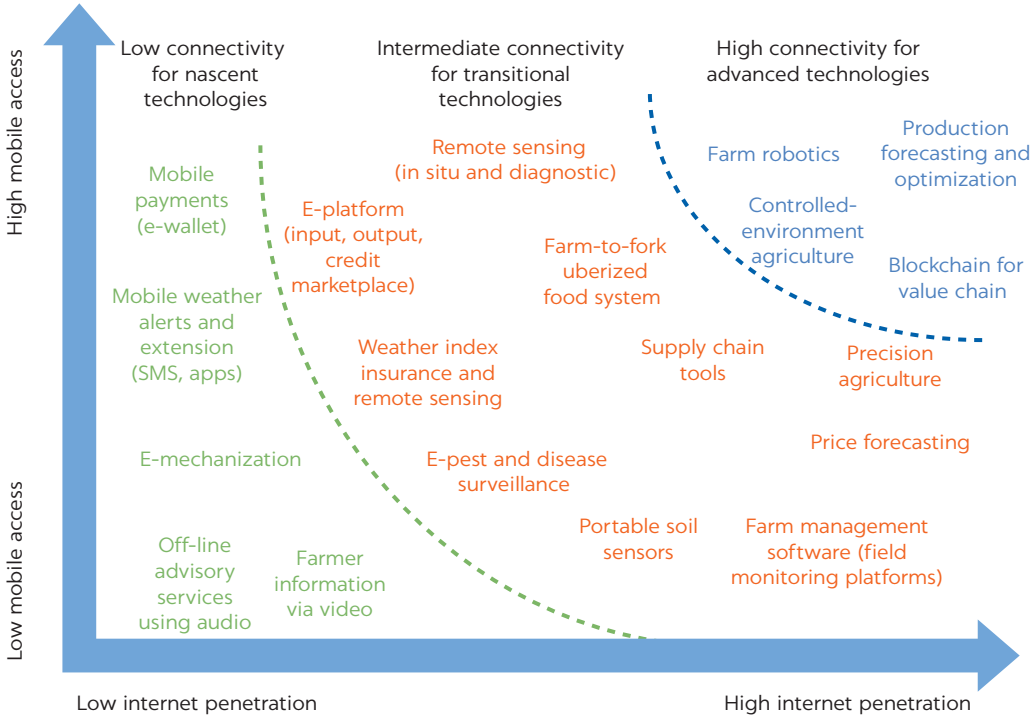
KEY FINDINGS

Disruptive agri-technology is an emerging sector in Sub-Saharan Africa. The number of scalable DATs founded in the past decade in Sub-Saharan Africa has spiked. Indeed, more than 70 percent of the DATs in the compiled database were founded in the past 10 years. Four key drivers are behind the acceleration in DATs in Sub-Saharan Africa: (1) low-cost and pervasive means of connectivity, (2) adaptable and more affordable tools, (3) advances in data analytics and exchange, and (4) increasing demand for contextualized agricultural solutions. Some African governments are driving the disruptive agri-technology agenda in their countries to improve agri-food outcomes. These drivers have provided an ecosystem conducive to DATs and are expected to continue shaping the prospects for DATs throughout the region.

More than 75 percent of scalable DATs in the database are digital. The remaining 25 percent are either focused on energy (solar), are producers or suppliers of bio-products for agriculture, or are aquaponics or hydroponics producers; thus, their primary technology is not digital. Although 75 percent of the scalable DATs are digital, the agriculture sector is still the slowest sector to digitize. Thus, it is important to proactively invest in the digital ecosystem for agriculture. Sub-Saharan Africa's digital ecosystem has progressed in the past few years such that most countries now have intermediate mobile penetration and internet connectivity. In these intermediate connectivity scenarios, DATs are using technology adaptations tailored to the agriculture sector.

Many of the digital technologies applicable to the agriculture sector can be deployed even in low-connectivity rural environments. DATs operate across a continuum, from low internet penetration and mobile connectivity to high digital connectivity. Most African countries have intermediate-level mobile and internet penetration (figure ES.1). However, digital accessibility is much lower in rural areas and varies greatly according to age, gender, and income. As such, reaching all African farmers with DATs will require a range of tools that can operate in different connectivity scenarios even within a country; for instance, low-connectivity scenarios require nascent technologies, intermediate-connectivity scenarios require transitional technologies, and high-connectivity scenarios can leverage advanced technologies. Examples of DATs adapted to low-connectivity environments include portable soil testers, short message service– (SMS-) based farmer education tools, interactive voice recordings, and off-line functioning platforms that can upload or receive data when a connection becomes available. More than 83 percent of the DATs operate as e-marketplace

FIGURE ES.1
Digital agriculture continuum



Source: DAT database.
Note: DATs operate across a range of connectivity scenarios. DATs = disruptive agricultural technologies; SMS = short message service.

or basic precision agriculture tools that do not require high connectivity and can operate with intermediate connectivity.

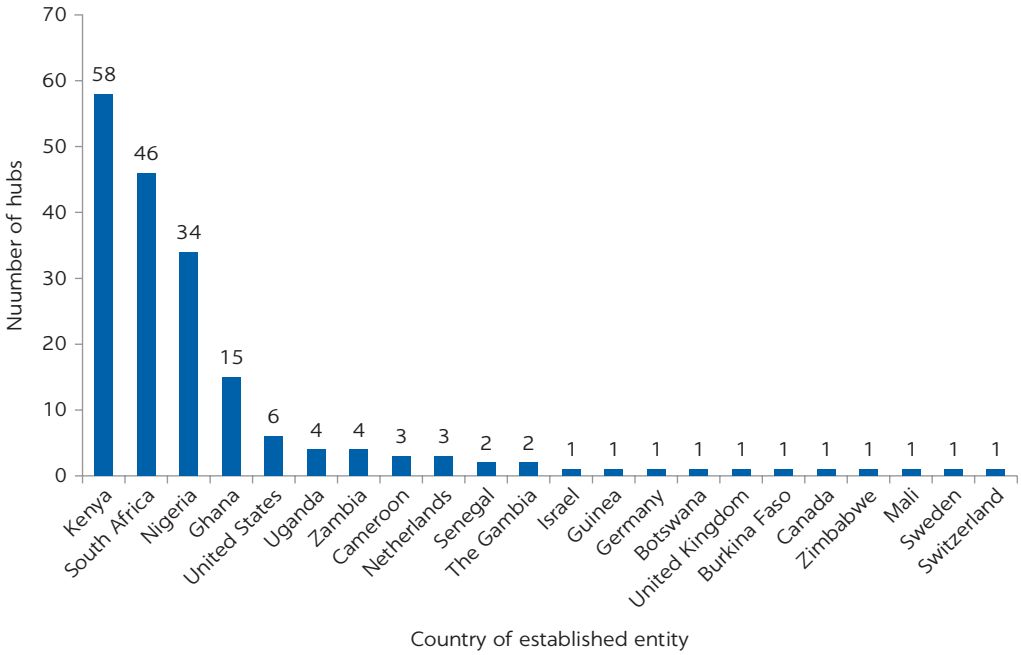
Some 32 percent of the scalable DATs in the database aim to enhance agricultural productivity, 26 percent are working to improve market links, 23 percent are engaged in data analytics, and another 15 percent are working on financial inclusion. Those DATs addressing market links, data analytics, and financial inclusion are all digital DATs. Some DATs also address more than one agricultural challenge. However, their proportion remains small, indicating further scope for moving from point-based solutions (addressing only one challenge) to bundled solutions (addressing multiple challenges). Indeed, bundled services such as digital platforms combining input supply with extension services, or linking farmers to buyers complemented by credit, may help increase adoption.

Of the scalable DATs in the database, 75 percent are operating in Kenya, South Africa, and Nigeria (figure ES.2). Kenya is a leading agri-technology hub, with approximately 60 scalable DATs operational in the country (according to the stocktaking database), followed by South Africa and Nigeria. Indeed, Kenya has one of the top-rated digital ecosystems on the continent. The country has the third-largest technology incubation and acceleration hub in the region. Kenya's financial sector is also characterized by a robust mobile money ecosystem, with more than 70 percent of the population using mobile money on a regular basis.

Major barriers in scaling up DATs in Kenya and Nigeria include limited access to finance, a challenging regulatory environment, infrastructure, and human capital. In aggregate terms, Kenya scored 3 out of 5 and Nigeria 2 out of 5 across the six ecosystem domains (figure ES.3). Both countries scored best on density, that is, the presence of networks that support productive relationships between

FIGURE ES.2

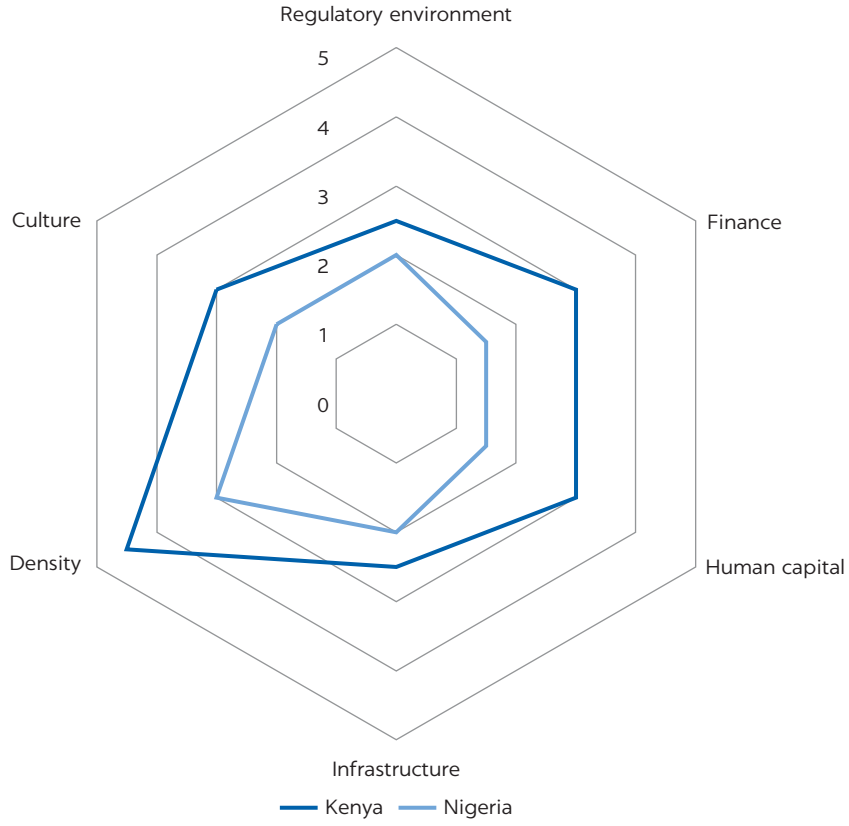
Scalable disruptive agri-tech hubs, by country



Source: Stocktaking activity.
Note: Preliminary findings from the stocktaking activity. *N* = 188.

FIGURE ES.3

Ecosystem assessment for Kenya and Nigeria



Source: Assessment based on global indicators.

different actors. Both countries scored relatively low on culture, which comprises the level of entrepreneurship promotion, research collaboration, economic freedom, and technology adoption. Despite the strategy to create an environment conducive to innovation, broader macro challenges need to be addressed for these countries to catch up with other global leaders in agri-technology innovation.

Other challenging aspects include low technology adoption among smallholder farmers and a lack of role models and mentoring for new entrepreneurs. In interviews, innovators highlighted the lack of appropriate growth capital to help them build operations to reach a significant number of users. Affordable debt capital is a major gap, particularly for DATs with significant working capital needs. A lack of a historical track record of successful DATs that have achieved scale or that have been acquired by larger firms hampers motivation and interest among potential DAT entrepreneurs and investors. Finally, despite the progress made toward mobile penetration and internet connectivity, Kenya and Nigeria—Sub-Saharan Africa's leading DAT countries—still rank low on technology use, especially among smallholder farmers.

Bringing together governments, entrepreneurs, investors, and other ecosystem actors is a powerful catalyst for scaling up DATs. There is immense scope for supporting DATs to turn them into successful, large-scale innovative enterprises for transforming food systems. Timely support and catalytic funding can send a strong signal to private investors to take on the residual risks in investing in DATs. One such example is Kenya's Twiga Foods. Launched in 2014, the company uses a technology platform to improve the supply chain from farmers to markets. Twiga Foods serves about 2,000 outlets a day through a network of 13,000 farmers and 6,000 vendors. The company has reduced typical postharvest losses in Kenya from 30 percent to 4 percent for produce brought to market on the Twiga network. In 2018, Twiga further scaled up and secured funding topping US$10 million from the IFC and TLcom Capital. This is a result of timely support from the US Agency for International Development in the form of a grant and different mentorship programs (Google Launchpad and GSMA Ecosystem Accelerator). The Innovation, Knowledge, and Challenge Conference organized as part of this study generated knowledge and momentum within Kenya's public sector and innovation ecosystem to lead the agri-technology agenda. It provided an important venue for participants to identify new areas of partnership and new partners. Indeed, 14 innovators were selected for inclusion in the first cohort of the One Million Farmer Initiative. The conference provided an interface for DAT players and ecosystem enablers and served as a model for providing training, mentorship, finance, and collaboration incentives across key stakeholder groups.

CONCLUSIONS AND RECOMMENDATIONS

While first-order challenges in agriculture (for example, irrigation, access to inputs, and so on) remain pressing, the adoption of DATs (especially digital DATs) is low in Sub-Saharan Africa. However, evidence shows that DATs can amplify the impact of "analog" investments. With regard to scale of operations, from 1,000 farmers to more than 600,000 farmers make use of particular DATs, depending on the delivery model, indicating the successful adoption of DATs within the agri-food system. In this regard, DAT ecosystems appear to be at an inflection point at which several trends are emerging:

- A profusion of small companies are starting to bundle their services (for example, input supply with extension) to achieve a wider scale and deeper and stronger financial viability.
- Emerging DATs can operate successfully off line at the farm level, updating only when connected in urban areas.
- Farmer databases support DAT development and uptake; these databases are a major investment cost for start-ups.
- Well-developed mobile payment systems are an essential ingredient for most DAT enterprises to function effectively.
- Financial technology solutions are bridging liquidity gaps for farmers to the benefit of the entire supply chain, from input suppliers to off-takers. Examples include installment payment systems, very short-term loans, and insurance products.
- The biggest challenge is not the existence of solutions, but rather the framework within which these DAT solutions would operate and be sustained. Leading ministries of agriculture are seeking to systematically invest in knowledge, innovation, and the incubation ecosystem for digital, women, and youth entrepreneurship.

DATs have demonstrated early signs of creating an impact by leapfrogging the conventions. As such, they hold the potential for accelerating the outcomes of the agri-food system. The pace at which DATs will accentuate these positive outcomes depends upon the innovation ecosystem in Sub-Saharan Africa. Further areas of research for agri-technology include coverage and adoption of DATs, such as in an Enterprise Survey measuring technology adoption across agriculture sectors.

Policy opportunities to foster digital innovation include policies to promote competition, effective intellectual property protections, incentives for technology diffusion, innovation in public service provision related to e-vouchers or e-extension, investments related to digital skills, open science initiatives, research infrastructure, and ongoing dialogue with the private sector to adapt to evolving needs. Public investments to promote DAT development are most effective when they follow the "cascade" approach to ensure that they crowd in, rather than crowd out, private investments.

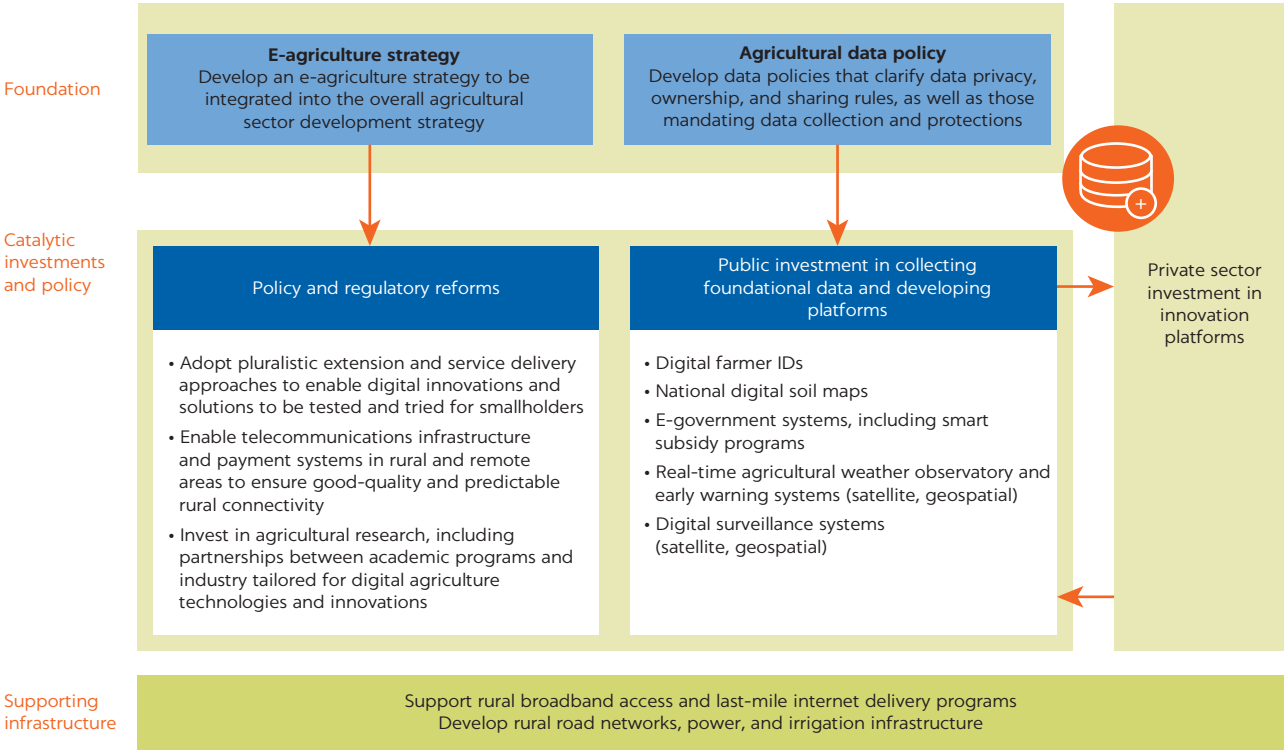
Governments can support DATs as follows (see figure ES.4):

1. *Invest in policies and platforms for data collection and access from public and private sources*. This investment will enable the development of appropriate products and services for smallholders. It will also develop a foundation of data for evidence-based policy making. Digitizing farmer data would enable the development of data-based and digitally enabled products and services. Access to good-quality data will aid in the development of innovative service delivery and products.

2. *Invest in an e-agriculture strategy*, which includes policy for pluralistic extension and service delivery approaches to enable digital innovations and solutions to be tested and tried for smallholders. Most of these solutions require partnerships between input suppliers, service providers, and digital innovators. Many existing agricultural policies have some scope for trying alternative and pluralistic approaches. It is difficult to develop these solutions in the absence of an enabling agriculture policy environment.

FIGURE ES.4

Potential entry points to facilitate the broader adoption of digital technologies and improve food system outcomes



Source: World Bank.

3. *Invest in e-governance systems for all public services and resources being administered through ministries of agriculture*. Channeling input subsidies and other incentives through digital services is also critical for the development of products and services.
4. *Invest in enabling policies for telecommunications infrastructure and payment systems in rural and remote areas* to enable good-quality and predictable rural connectivity. Connectivity for smallholder farmers and service providers would enable better access to services and digital solutions.
5. *Invest in an agri-technology start-up policy* to enable innovators in the digital space to operate and grow. In parallel, invest in the enabling ecosystem at country, regional, and international levels for the agri-technology sector to grow.

NOTES

1. All digital solutions do not require connectivity. Data require connectivity. Stored data or videos can be used off-line through devices.
2. The One Million Farmer Initiative is a three-year partnership that will link 1 million Kenyan farmers across 14 different agricultural value chains and 45 counties in Kenya to a digitally enabled platform. The platform will integrate and coordinate the activities of leading Kenyan-focused DATs. The One Million Farmer Initiative will build on and link to existing World Bank projects in Kenya, most notably the Kenya Climate Smart Agriculture Project and the National Agricultural and Rural Inclusive Growth Project.

Abbreviations

ASTI	Agricultural Science and Technology Indicators
CDAT	Crop Disease Alert and Tracking
DAT	disruptive agricultural technology
GDP	gross domestic product
GIZ	German Development Cooperation
GPS	Global Positioning System
GSMA	Global System for Mobile Communications Association
ICT	information and communication technology
IFC	International Finance Corporation
M&E	monitoring and evaluation
MSMEs	micro, small, and medium enterprises
PPP	public-private partnership
R&D	research and development
SMS	short message service
USAID	US Agency for International Development
VC4A	Venture Capital for Agriculture

1 Introduction

THE PROMISE OF SUB-SAHARAN AFRICA'S AGRI-FOOD SYSTEM

Sub-Saharan Africa's agri-food system is critical for the region's economic growth, poverty reduction, food security and nutrition, and employment. Agri-food systems refer to the agricultural system "from farm to fork," including input supply, farming, marketing, agri-processing, and exports. Agriculture contributes about 15 percent of gross domestic product (GDP) in Sub-Saharan Africa, although its contribution varies widely across countries, from as high as 50 percent to as low as 3 percent (OECD 2016).

With respect to poverty reduction, half of the world's extreme poor live in Sub-Saharan Africa, and this share is increasing. Evidence shows that a 1 percent increase in agricultural GDP reduces poverty, on average, by more than 1 percent, whereas a 1 percent increase in industry or services GDP reduces poverty by less than one-half of 1 percent (Christiaensen and Martin 2018). Agriculture will be key to eliminating extreme poverty, given that it is the main economic activity for most of the region's rural poor.

Agri-food systems are also important for food security, given that one-quarter of the continent's population is undernourished. By 2030, the continent will have half a billion more people to feed—a 42 percent increase (United Nations 2015). On the positive side, Africa's growing domestic food markets will represent a trillion dollar opportunity by 2030 (World Bank 2013), an important opportunity for farmers and agribusinesses.

Finally, agriculture is central to African job growth. More than 330 million new entrants will join the African labor force over the next 20 years, and the agri-food system could potentially absorb about 70 percent of these new entrants (NEPAD 2013). At present, agriculture provides more than 70 percent of employment in most African countries. Thus, the agri-food system can—and needs to—play a key role in accelerating growth, ending poverty and hunger, and contributing to creating jobs in Sub-Saharan Africa.

THE NUMEROUS CHALLENGES FACING AFRICA'S AGRI-FOOD SYSTEM

Africa's agri-food system is constrained by several challenges that limit its potential. Agricultural productivity remains one of the central challenges. Cereal yields are not rising fast enough to meet demand. For example, if projected food demand in 2030 is to be met by productivity gains alone, cereal yields will need to increase at a rate of 3 percent a year, about one-third higher than the 2.2 percent rate achieved during 2000–14 (Meyfroidt 2018). Climate change is also affecting food production and increasing volatility across all regions of Africa. The recent Intergovernmental Panel on Climate Change report (Voegele 2018) warned that global warming of 2 degrees will cause corn yields to shrink by 15 percent. In Africa, the decline could reach 20 percent if temperatures rise by 3 degrees Celsius, which would cause corn production to entirely collapse in some regions (Voegele 2018).

Several other challenges inhibit the efficiency, equity, and sustainability of the system. These challenges range from crop losses due to disease and pest management to lack of access to inputs, advisory services, markets, and finance, and from limited data analytics (for informed decision-making) to energy access for agriculture. This book uses an agricultural challenge–driven framework to classify the diverse agricultural challenges into five thematic areas: agricultural productivity, market access, financial inclusion, data analytics and intelligence, and alternative energy access (table 1.1):

1. *Productivity.* Cereal yields have accelerated in Sub-Saharan Africa since the 1990s (doubling the cereal yield growth rate), but they are not rising fast enough to meet growing food demand. If projected food demand in 2030 in Sub-Saharan Africa is to be met by productivity gains alone, cereal yields will need to increase by 3 percent a year, about a third higher than the 2.2 percent rate achieved during 2000–14, notwithstanding climate change's negative impacts and potential development trade-offs, that is, with the environment (Meyfroidt 2018). The situation in the livestock sector in Sub-Saharan Africa is similar. Growth in productivity has been slow for numerous reasons, including increased reliance on rainfed agriculture, weak reach and uptake of advisory and extension services, lack of access to climate-smart practices, and—critically—limited access to improved agricultural production inputs

TABLE 1.1 Agricultural challenge–driven framework

AGRICULTURAL CHALLENGE	CHALLENGE FRAMEWORK
Agricultural productivity	Extension and advisory services and climate-smart agriculture; pest and disease management
Market links	Help to link farmers to markets, including digital platforms to sell farm produce
Farmer financial inclusion	Access to credit and savings products, insurance, and other innovative financial services for farmers
Data analytics and agricultural intelligence	Availability of data for policy making and for developing private products and services; data infrastructure for deploying remote-sensing and mapping technologies; precision agriculture tools
Energy for agriculture	Access to energy for irrigation, cold-chain, and processing

Source: World Bank.

(for example, seeds, fertilizer, pesticides) and mechanization for production (such as land preparation equipment like tractors and irrigation).

2. *Market links.* A majority of smallholders in Sub-Saharan Africa participate in poorly structured "loose" or "semi-loose" value chains rather than in "tight" commercial value chains that are linked to large domestic or export-oriented buyers. This means that farmers struggle to find guaranteed buyers for their produce (with a range of downstream effects on their earnings). When they do sell their produce, farmers struggle to secure sufficiently high prices and lose substantial value to various intermediaries between the farm gate and the end buyer. Obstacles to market access include asymmetric information on production volumes and prices, perceived or actual low quality of produce, limited knowledge of and physical access to high-quality buyers, and timing effects (for example, markets exist, but a farmer is unable to get produce to the market at the right time).

3. *Farmer financial inclusion.* Access to agricultural finance for small and medium farmers is still limited in Kenya. For instance, only 10 percent of smallholder farmers have access to financial services, including credit and insurance, according to FarmDrive.[1] The quantity of credit available to the agriculture sector is also inadequate, with only 1 percent of credit supply flowing to the sector. Factors that constrain financial access include lack of reliable data to support agricultural lending decisions, lack of collateral to secure financing, high transaction costs for accessing and delivering financial services to rural areas, and lack of data platforms for assessing risk and delivering financial services (for example, high costs of traditional claims processing for agri-insurance). Additionally, the high cost of credit translates into a lack of demand for credit by farmers.

4. *Data analytics and intelligence.* The rapid development of data infrastructure and the profusion of digital technologies and low-cost precision agriculture devices (information and communication technology, drone aerial surveillance, satellite geographic information systems, weather data analytics, blockchain, internet of things) have the potential to deliver farm-level, geospatial, and real-time analytics to inform policies and targeted investments by governments, agri-businesses, and various types of intermediary-service providers. In many cases, generating and accessing large-scale national data sets is a costly challenge for any individual player in the market. In other cases, even when data sets are affordable, they are simply not accessible and not shareable across silos (such as private sector data sets that companies may have few incentives to share with the broader ecosystem). Certain types of data have strong public good components and rely on substantial upfront investments into data capture and analytics infrastructure that the private sector may be unwilling to subsidize (for example, weather data, soil data).

5. *Energy access for agriculture.* Energy is an important enabler for the agriculture sector to realize its growth potential, especially for power-intensive value chains. The need for energy is distributed across the life of the crop—from mechanized irrigation to processing (milling , drying, chilling, and so on) for final consumption (packaging, bottling, and the like). Energy demand for irrigation varies by the types of irrigation systems, which range in scale from manual to surface flooding and from localized to

center pivots. Postharvest and primary processing and secondary processing are growth areas. Milling is likely to increase significantly owing to the expected demand growth for such grains as maize (corn), wheat, and rice. Similarly, such staples as cassava are expected to experience increased demand for processing because of their perishable nature and use as an industrial input in the manufacture of other products (for example, glue in the case of cassava). Creating opportunities to piggyback viable rural energy access onto local agricultural development will depend on the scale and profitability of agricultural operations, crops, terrain, types of processing activity, and other site-specific local conditions (Banerjee et al. 2017).

Although significant strides have been made in recent years to transform the system, it is far from harnessing its full potential. Thus, it is essential that these challenges be addressed using a different approach. The emerging agricultural technologies in Africa are disrupting the status quo system and providing an innovative approach to addressing system-wide challenges (table 1.2). For instance, some of the emerging disruptive agricultural technologies (DATs) are significantly increasing access to inputs, credit, and financial products; reducing inequalities in access to information, thereby providing knowledge and advisory services resulting in enhanced productivity; linking markets to farmers; and helping farmers make more precise decisions about resource management by providing, processing, and analyzing an increasing amount of data faster, thereby

TABLE 1.2 Agricultural challenges and relevant examples of DATs in Africa

CHALLENGE FRAMEWORK	AGRICULTURAL CHALLENGES	STANDARD AGRICULTURAL SOLUTIONS	DAT SOLUTIONS	ILLUSTRATIVE DAT EXAMPLES
Agricultural productivity	Insufficient advisory and climate-smart services	Producer organizations, extension agents, radio, TV	Agricultural extension and advisory services delivered through videos and platforms linking experts	Digital Green in Ethiopia; Precision Agriculture for Development in Kenya
	Limited access to inputs (tractors) for land preparation	Manual, animal-aided, mechanized	Digitally enabled tractor-hiring services	Hello Tractor in Nigeria
	No systematic pest and disease management	Observe and respond	Real-time alert systems	Waterwatch Cooperative in Kenya
Market links	Poor market access	Farmer cooperatives, intermediaries	Digital platforms for finding buyers and linking buyers and sellers	Tulaa in Kenya; Maano in Zambia; Farmshine in Kenya; Zowasel in Nigeria
Farmer financial inclusion	Insufficient or unfair access to credit and financial products	Moneylenders, family and friends	Platforms for input credit, e-wallets, and insurance products	Agri-wallet in Kenya
Data analytics and agricultural intelligence	No or inadequate access to data for informed decision-making	Intuition based on observation, no solution	Portable soil testers, satellite images, remote sensing	Agrocares, based in the Netherlands and operating in Kenya; UjuziKilimo in Kenya
Energy for agriculture	Poor irrigation infrastructure	Rainfed, manual, gravity-aided	Solar-powered irrigation pumps	SunCulture in Kenya

Source: World Bank.
Note: DATs = disruptive agricultural technologies.

making small-scale farmers more competitive. As such, it becomes important to define and study the nature of DATs as an emerging phenomenon that can act as a future catalyst.

DISRUPTIVE AGRICULTURAL TECHNOLOGIES AS A CATALYST FOR CHANGE

The World Bank Group defines DATs as digital and nondigital innovations that enable smallholder farmers to leapfrog their current constraints and improve their yields, incomes, nutritional status, and climate resilience. These technologies range from mobile apps to digital identities for farmers, to solar applications for agriculture, to portable agriculture devices, to bio-fortified foods.

In defining DATs, it is critical to describe the meaning of disruption in the agricultural context. DATs are technologies or business innovations that make the farmer an active agent in the agri-food system by either accelerating agri-food outcomes three- to fivefold or by circumventing the conventions of the value chain to achieve the same or better or more efficient agri-food outcomes. For instance, farmers can actively seek real-time, low-cost, tailored, precise, and actionable information regarding pest and disease management, thus increasing agricultural productivity or reducing crop loss by multiple factors. If a crop disease outbreak occurs, alerts can be actively provided to farmers in advance, thus preparing them to manage the outbreak.

A similar service is provided by Waterwatch, which is a Netherlands-based company operating worldwide. Waterwatch developed the Crop Disease Alert and Tracking (CDAT) solution for potato farmers. Potatoes are, for example, the second-largest crop produced in Kenya, after maize, and the crop currently suffers from a harvest loss of approximately 40 percent from pests and disease. CDAT is a mobile application that combines weather data, satellite imagery, and pictures taken by farmers with their smartphones (for image recognition). The solution provides alerts before a disease occurs and can track the development of a disease whenever a crop is infected. Farmers can also seek information from CDAT by posting pictures of pests on the application. The combination of technologies—satellite images, weather information, farmer images, and artificial intelligence on low-end phones—ensures that the information can be provided with unprecedented precision (that is, spatial resolution) and accuracy. With CDAT, the yields and income of smallholder farmers are expected to increase as a result of a higher crop survival rate.[2]

Waterwatch exemplifies the definition of disruptive agricultural technology by circumventing the conventions of the value chain and making farmers actively involved in managing the health of their crops to derive better results. Its technology also clearly illustrates the potential of DATs in addressing the constraints of smallholders. Similar disruptive technologies need to be nurtured in a thriving ecosystem by reducing barriers to entry and increasing adoption among farmers. Once these disruptive technologies reach substantial scale, they hold the potential to rapidly accelerate the achievement of agricultural outcomes and provide dividends for the smallholder community.

DATs: POTENTIAL TO IMPROVE EFFICIENCY, EQUITY, AND SUSTAINABILITY OF THE AGRI-FOOD SYSTEM

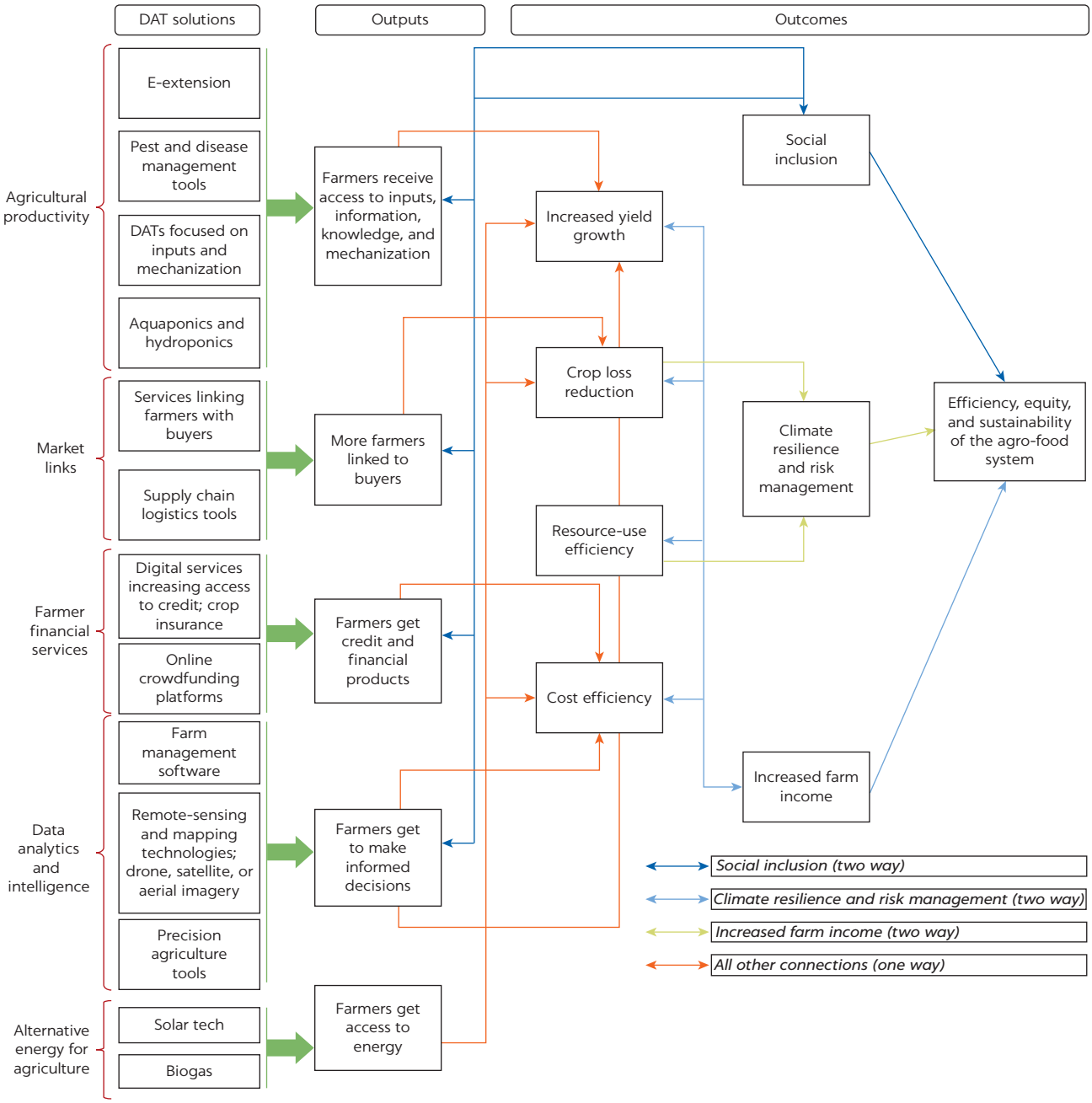
DATs are demonstrating early indications of a positive impact on addressing food system constraints. For instance, Precision Agriculture for Development focuses on sending short message service (text messages) to smallholders with agricultural advice. It serves more than 6 million farmers in seven countries, four of which—Ethiopia, Kenya, Rwanda, and Uganda—are in Africa.[3] An impact assessment of Precision Agriculture for Development conducted by Harvard University and Innovations for Poverty Action in Kenya (2013) demonstrated that sending text messages with agricultural advice to smallholder farmers increased yields by 11.5 percent relative to a control group (Casaburi et al. 2014). Another example is Reuters Market Light services, which covers more than 200,000 smallholder subscribers in India for a cost of US$1.50 per month. The farmers receive four to five messages per day regarding prices and commodities as well as advisory services. Preliminary evidence suggests that, collectively, the service may have generated US$2–3 billion in farmer income. In addition, more than 50 percent of these farmers have reduced their spending on agricultural inputs (World Bank 2017).

DATs hold the potential to improve the efficiency, equity, and sustainability of the food system. To enhance efficiency, DATs can (1) improve the use of capital, including machinery and equipment, in the food system, thereby increasing its technical and allocative efficiency (for example, Hello Tractor in Nigeria and Trotro Tractor in Ghana connect tractor owners and smallholder farmers in Sub-Saharan Africa through a digital tractor-sharing application); (2) facilitate the acquisition of skills and knowledge needed for agricultural production, thereby improving labor efficiency and the optimal use of inputs (Waterwatch Cooperative's pest and disease management in Kenya alerts farmers about when and how to manage pests and disease, thus improving labor and resource use); (3) improve farmers' decision-making through accurate, timely, and location-specific price, weather, and agronomic data and information that will become increasingly important in the context of climate change (Precision Agriculture for Development in Kenya and Ethiopia sends text messages to smallholders with location-specific weather as well as agronomic advice); and (4) reduce costs associated with matching producers and consumers, which will help expand output markets and improve producer access to inputs (AgroXchange in Nigeria creates a digital profile of farmers that facilitates access to market as well as to credit and inputs).

Improved production decisions and efficiency can help increase farmers' profits. DATs have the potential to improve equity by addressing unequal access to information, knowledge, technologies, and markets, thereby improving the relative incomes of poor people. In addition, improved traceability can help increase food safety, with attendant positive health effects. Regarding the environmental sustainability of the food system, DATs can improve the use of natural capital such as water and land, as well as the use of inputs, such as fertilizers (Precision Agriculture for Development in Ethiopia, Kenya, Rwanda, and Uganda). For example, remote-sensing technologies can measure water use and monitor net withdrawal of groundwater, which can help determine sustainable use targets for better irrigation water management (World Bank 2019).

Figure 1.1 shows the possible theoretical outcomes that DATs can achieve when the solutions are geared toward specific agricultural challenges.

FIGURE 1.1
DAT theory of change



Source: World Bank.
Note: DAT = disruptive agricultural technology.

STRUCTURE AND PURPOSE OF THE BOOK

What does it take to create and foster ecosystems conducive to DATs? How can governments and partners, such as the World Bank, help local entrepreneurs, innovators, youth, and agribusinesses confront institutional challenges in the industry? This book distills lessons from three activities that, taken together, identify agriculture policies and investments for developing the DAT ecosystem in Africa.

The first activity was a "stocktaking analysis" with the objective of understanding the landscape of existing DATs in Sub-Saharan Africa. The activity assessed the numbers, scope, trends, and characteristics of disruptive technology innovators in the agriculture sector in Africa. This activity culminated in a novel database based on the definition of DATs with a specific set of exclusion and inclusion criteria (see appendix A). Furthermore, the stocktaking database had a special focus on the scale of DAT operations; that is, it focused on DATs that have a proven business model and are poised to scale up rapidly. This is distinct from as well as complementary to the work undertaken by different teams at the World Bank Group as they focus *either* on initial stages of DATs (incubation phase) (infoDev) *or* on later-stage start-ups (IFC). See figure A.1 in appendix A for an explanation of start-up growth phases. Chapter 2 provides a detailed description of the stocktaking exercise.

The second activity was a comparative analysis of Sub-Saharan Africa's two most successful DAT ecosystems, in Kenya and Nigeria, which together account for half of active DATs. The objective of these two ecosystem case studies was to understand the successes, challenges, and opportunities faced by each country in fostering an innovation ecosystem conducive to scaling up DATs. The World Economic Forum (2018) defines "innovation ecosystem" as an environment that enables entrepreneurs to engage in iterative processes. The innovation ecosystem analysis thus is crucial given that scaling up DATs requires a unique set of conditions in the country, including cultural and organizational dimensions such as mentorship and technical support to individual entrepreneurs. The ecosystem analysis reveals how different system actors (public sector, private sector, and development partners) can contribute to DAT growth, scaling up, and adoption. The case study analysis focused on six dimensions of the innovation ecosystem in Kenya and Nigeria: finance, regulatory environment, culture, density, human capital, and infrastructure. Chapter 3 reports the findings of these case studies and shows how understanding the dynamics of the ecosystem can guide effective government interventions to help scale up DATs.

The third activity was the Innovation, Knowledge, and Challenge Conference, which brought together more than 300 key stakeholders from large tech companies, agri-business companies, and public agencies; government representatives (such as governors and county agriculture ministers); experts from research and academic institutions; representatives of financial institutions and foundations; as well as venture capitalists and donors. The conference convened diverse DAT actors and ecosystem enablers to generate substantial knowledge about the challenges and opportunities facing Kenyan DAT entrepreneurs, government agencies, and food system actors that are relevant to the wider Sub-Saharan Africa region. The conference's findings and key takeaways are captured in the Kenya case study described in chapter 3 and throughout this book.

The book concludes with recommendations for policies and investments to develop the DAT ecosystem in Kenya, Nigeria, and Sub-Saharan Africa more broadly, thereby helping to scale up high-potential DATs across the continent. Although the book generates substantial new knowledge, it also raises new questions and highlights information gaps; hence, chapter 4 recommends areas for future research.

NOTES

1. For more information on FarmDrive, see https://farmdrive.co.ke/.
2. For more information on Waterwatch's Crop Disease Alert app, see https://waterwatchfoundation.com/crop-disease-alert/.
3. For more information on Precision Agriculture for Development, see https://precisionag.org/.

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2 Taking Stock of DATs in Sub-Saharan Africa

METHODOLOGY

The analysis presented in this chapter is based on a novel database of disruptive agricultural technologies (DATs) in Sub-Saharan Africa that has been curated through secondary research. This database of 194 DATs forms the basis of the analysis in this book given these DATS' proven products and growth potential. The database had identified 194 DATs as of May 10, 2019 (box 2.1). This database can be expanded as more DATs are discovered routinely and are added to the database file. Therefore, this database is a unique snapshot in time of a dynamic sector and is not meant to be exhaustive.

Because the database is built primarily on company profile sources and these company profile sources focus on for-profit companies, more than 95 percent of the identified DATs in the database are for-profit organizations with operations in Sub-Saharan Africa. The stocktaking database has a special focus on the operational scale of DATs, and thus all 194 DATs in the database are identified as scalable DATs. Unless otherwise noted, all figures and tables in this chapter are derived from the database and its analysis and they refer to scalable DATs only. (A description of the detailed methodology used for inclusion and exclusion can be found in appendix A.)

RISING NUMBER OF DATs IN SUB-SAHARAN AFRICA OVER THE PAST DECADE

According to the DAT database, the number of DATs founded in Sub-Saharan Africa has increased rapidly over the past decade. Figure 2.1, based on an analysis of the DAT stocktaking database, shows that disruptive agri-technology is an emerging sector, with more than 70 percent of the DATs having been founded in the past decade. Given this surge in DATs in Sub-Saharan Africa, it is important to understand the driving factors.

Four key supply-side drivers influence DATs in Sub-Saharan Africa: (1) low-cost and expanding mobile and internet connectivity, (2) adaptable and more affordable tools, (3) advances in data analytics and exchange, and (4) increasing

BOX 2.1

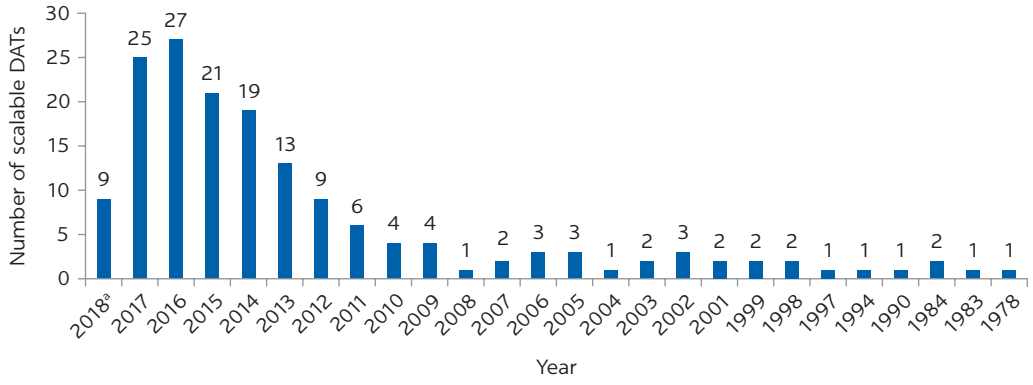
Inclusion and exclusion criteria

The step-by-step filtering methodology described in this box led to the identification of 194 scalable disruptive agricultural technologies (DATs):

- Data were collected from a variety of secondary research sources (including company profile sources such as Tracxn, Pitchbook, and Crunchbase; Google searches; literature reviews; and others). A total of 434 for-profit and nonprofit organizations were downloaded from across the continent.
- Of the initial 434 organizations, 194 were identified as scalable DATs if they met the following inclusion criteria:
  - Current operations in Sub-Saharan Africa, excluding North Africa, irrespective of the geography of business entity
  - Solutions applicable for crops, livestock, and horticulture
  - Solutions have farmer as ultimate consumer
  - Solutions address one of the five agricultural challenges in the DAT framework
  - Organizations had developed their solutions and had potentially tested their solutions with a small number of farmers (DATs in the validation phase with at least minimum viable product [MVP]). (See figure A.1 in appendix A for more details.)
  - Organizations have an operational website or are widely discussed in the media or by development partners
- Of the initial 434 organizations, 240 were excluded based on the following criteria:
  - Solutions were focused on retail households (such as food-delivery applications) or hobbyists and not for farmers
  - Solutions with operations in North Africa only, with no presence in Sub-Saharan Africa
  - Traditional agro-processing, milling, or exporting companies, which formed a large proportion of the 240 excluded organizations

FIGURE 2.1

Increased number of DAT solutions in the past four decades



Source: DAT database.
Note: Preliminary findings from the stocktaking activity. *N* = 165. DATs = disruptive agricultural technologies.
a. The data for 2018 are not complete.

demand for contextualized agricultural solutions. In addition, some African governments are driving the agri-technology agenda in their countries to improve agri-food outcomes. These drivers have provided an ecosystem conducive to the expansion of DATs and are expected to continue shaping the prospects for DAT solutions (World Bank 2017).

The cellular market is increasingly characterized by low costs and pervasive connectivity. Cellular subscriptions are skyrocketing in Sub-Saharan Africa, with 444 million unique mobile subscribers (44 percent the population) (GSMA 2018b) and mobile broadband connections reaching 38 percent of the population in 2017. Between 2012 and 2017 the average selling price of smartphones fell to less than US$120 in most markets, with smartphones priced at less than US$100 now also available in African countries (*ZDNet* 2018).

More adaptable and affordable tools are becoming prevalent in the market. The intuitive design of many technologies and their capacity to convey information visually or audibly make them more useful to people with limited formal education or exposure to technology. Feature phones are making mobile-based applications suitable for poor and isolated communities through the provision of simple services (for example, short message service [SMS, or text messages], call centers, interactive voice recording). Geospatial mapping tools are also bringing information to nonspecialist users. Between 2004 and 2014, the average cost of internet of technology sensors dropped by more than half, that is, from US$1.30 to US$0.60. Furthermore, prices are expected to drop another 37 percent, to US$0.38, by 2020 (Dukes 2018).

Advances in data analytics and exchange are also affecting the market. With big data and artificial intelligence, advances in analytics are transforming enormous amounts of digital data into a form decision-makers can use. Cloud computing offers access to numerous shared computing resources through the internet, including shareable tools, applications, and intelligently linked content and data (World Bank 2017).

The region is experiencing increasing demand for contextualized agricultural solutions. Agricultural technology is becoming a feasible market, with various technologies coming together to meet agricultural challenges. For instance, with market liberalization, Sub-Saharan African farmers face new food safety regulations. Distributed ledger technologies, blockchain, food-sensing technologies, supply chain management and logistics (for example, Twiga Foods in Kenya), and data analytics and artificial intelligence (which provide traceability services) are allowing farmers to meet these new food safety regulations. Similarly, several new technologies help farmers use their resources more efficiently. For example, precision agriculture brings together a wide array of technologies, such as Global Positioning System (GPS) guidance, control systems, sensors, robotics, drones, autonomous vehicles, variable rate technology, GPS-based soil sampling, automated hardware, telematics, and software.

A variety of factors are driving DAT adoption. For example, rising incomes, populations, and urbanization are increasing the domestic demand for food. The export demand for food is also growing. Regarding technology, an increasing number of farmers use mobile phones. In addition, agribusinesses account for a growing share of production, and agro-processors and exporters are seeking to ensure a more stable supply of produce.

Governments in Sub-Saharan Africa (especially Ethiopia and Kenya) are also gradually realizing the potential of agriculture technology, helping drive adoption and growth. For instance, at the macro level, public authorities can leverage agri-technology in several ways. Satellite and remote-sensing data can be used by public authorities for several purposes, including (1) adopting efficient land subsidy policies, (2) monitoring existing controls, (3) assessing changes in crop locations, (4) monitoring any issues that could pose a risk for national or international food security, (5) monitoring carbon absorption of plants for the purpose of climate change emissions monitoring, and (6) monitoring waterways at risk of agricultural fertilizer runoff (Catapult 2017).

The Ethiopian Soil Information System (EthioSIS) project exemplifies the way in which governments in Sub-Saharan Africa are eagerly leading the agri-technology agenda. The EthioSIS project, led by the Agricultural Transformation Agency, is using remote-sensing and satellite technology to create a digital map of the country's soil. Based on these data, Ethiopia has revamped its fertilizer recommendations. For the past 30 years, farmers have followed a blanket recommendation of 100 kilograms of diammonium phosphate and 100 kilograms of urea. With the soil map, Ethiopian farmers are applying tailored blends that are scientifically proven to provide the greatest yields in their specific geographies—with the least environmental impact. By combining powerful, context-specific data with the connectivity of mobile phones, Ethiopia is envisioning delivering valuable real-time information to farmers to support them throughout the agricultural season (Annan, Dryden, and Conway 2015). Other Sub-Saharan African governments have adopted similar public initiatives, as shown in table 2.1.

TABLE 2.1 Examples of World Bank–financed initiatives promoting disruptive technologies for agriculture

COUNTRY	AGRICULTURAL PRODUCTIVITY	MARKET LINKS	FINANCIAL INCLUSION	DATA ANALYTICS AND INTELLIGENCE	OTHERS
Benin	E-extension	E-services			Rural information and communication technologies infrastructure
Burkina Faso	E-extension				
Burundi	Coffee tree census using satellite images				
Cameroon		Agricultural market intelligence	Digital financial services		Digital capacity building for rural youth
Central African Republic				Geo-enabled M&E	
Chad			E-vouchers		
Côte d'Ivoire	E-extension, mobile-based weather alerts	E-services	E-vouchers		Rural information and communication technologies infrastructure; web-based land information system
Democratic Republic of Congo				Agriculture Observatory; geo-enabled M&E	

continued

TABLE 2.1, *continued*

COUNTRY	AGRICULTURAL PRODUCTIVITY	MARKET LINKS	FINANCIAL INCLUSION	DATA ANALYTICS AND INTELLIGENCE	OTHERS
Ethiopia				Agriculture Observatory; EthioSIS (remote sensing and satellite technology)	
Ghana	E-extension				
Guinea	E-extension				
Kenya		Big data for e-market platform		Agriculture Observatory	
Mali			E-voucher		
Madagascar		Digitalization of value chain data		Agriculture Observatory; landscape mapping with remote sensing; land information system	
Mozambique				Agriculture Observatory; landscape mapping with remote sensing; digital (tablet) monitoring	
Nigeria		E-service	E-voucher		
Republic of Congo				Geo-enabled M&E	
Rwanda	E-extension			Landscape mapping with remote sensing	
Senegal			E-vouchers		
Uganda	E-extension		E-vouchers	Geo-enabled M&E	
Zambia			E-vouchers		

Source: Based on December 2018 survey of World Bank Agriculture Projects.
Note: M&E = monitoring and evaluation.

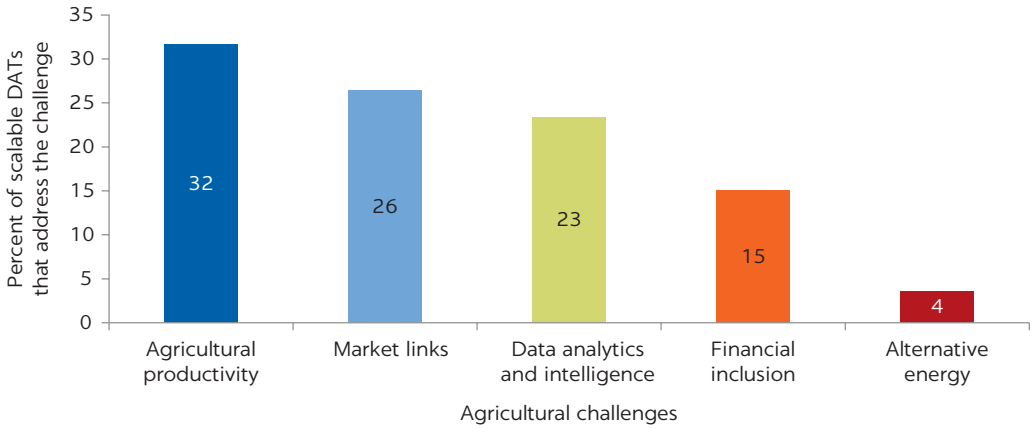
DATs: PROVIDING SOLUTIONS TO AGRICULTURAL PRODUCTIVITY AND MARKET LINKS

Figure 2.2 shows that most DATs from the database are providing solutions for two key agricultural challenges: productivity (32 percent) and market links (26 percent). Very few DATs offer bundled solutions. Indeed, most DATs are point based and are focused on solving niche problems. For instance, Waterwatch Cooperative in Kenya is a point-based solution that only addresses disease and pest management. However, the average African farmer faces many challenges, including access to inputs, markets, credit, and irrigation. Thus, there is scope for bundling solutions to make them more adaptable to farmers' needs and priorities. For example, Waterwatch seeks to create an "ecosystem" in which its monitoring tool can be used in conjunction with insurance products, agro-chemical procurement, and extension services.

The DAT framework includes several services and solutions that contribute to increasing agricultural productivity. These services and solutions include video tools and SMS with agronomic information, climate-smart advisory, weather information, and extension services (for example, Digital Green in Ethiopia and Precision Agriculture for Development in Kenya); chatbot services; peer-to-peer learning platforms (such as Farm.ink across Sub-Saharan Africa); pest and disease management tools (Waterwatch Cooperative in Kenya); medical assistance tools for livestock (DigiCow in Kenya); digital services that increase farmers' access to inputs and mechanization (Hello Tractor in Nigeria);

FIGURE 2.2

Percentage of DATs addressing selected agricultural challenges



Source: DAT database.
Note: Preliminary findings from the stocktaking activity. *N* = 193. DATs = disruptive agricultural technologies.

solutions increasing access to bio-fertilizers, bio-pesticides, or bio-products for agriculture (Real IPM in Kenya); and aquaponics and hydroponics with the farmer as the consumer (Kenrica in Kenya).

Market links defined by the DAT framework include several tools that aid farmers in producing high-quality, high-yield crops, as well as helping link them to markets, including digital platforms to sell farm produce. These tools, solutions, and services include services linking farmers with buyers (Tulaa in Kenya, Maano in Zambia, Farmshine in Kenya, Zowasel in Nigeria) and supply chain logistics and traceability (QualiTrace in Ghana and iProcure based in Kenya).

Financial services defined by the DAT framework include solutions that increase access to credit and savings products, insurance, and other innovative financial services for farmers. These solutions include digital services that increase farmers' access to credit (Agri-wallet in Kenya), services that increase farmer financial knowledge through training (Arifu in Kenya), services and solutions that increase access to crop insurance and generate credit scoring and creditworthiness of farmers (FarmDrive in Kenya and ACRE Africa in Kenya); and online crowdfunding platforms for farms (Agrikaab in Kenya and Farmfunded and Farmcrowdy in Nigeria).

Data analytics and macro-intelligence as defined by the DAT framework include solutions that provide data and data infrastructure for making informed decisions to farmers as well as to other actors in the value chain (policy makers, public agencies, and private service providers). These solutions include livestock identification; livestock and cattle management software (Ripplenami in the United States, Anitrack in Ghana); fish management software; farm-management software; cloud-based management information systems (Agrohub in Nigeria); remote-sensing and mapping technologies; drone, satellite, or aerial imagery (Astral Aerial and Oakar Services Ltd in Kenya, Geo-Gecko in Uganda); precision agriculture tools such as internet-of-things devices (HoneyFlow Africa in Nigeria); soil sensors; and soil testing (Agrocares, based in the Netherlands and operating in Kenya, UjuziKilimo in Kenya). For macro-intelligence, solutions such as aWhere and Gro-intelligence are important.

PHOTO 2.1

Solar-powered irrigation solution

Source: © Curt Carnemark / World Bank. Permission required for reuse.

Alternative energy for agriculture includes solutions that increase access to energy for irrigation, cold chain, and processing and are based on solar (see photo 2.1), wind, or renewable energy (Coldhubs in Nigeria, SolarFreeze and SunCulture in Kenya).

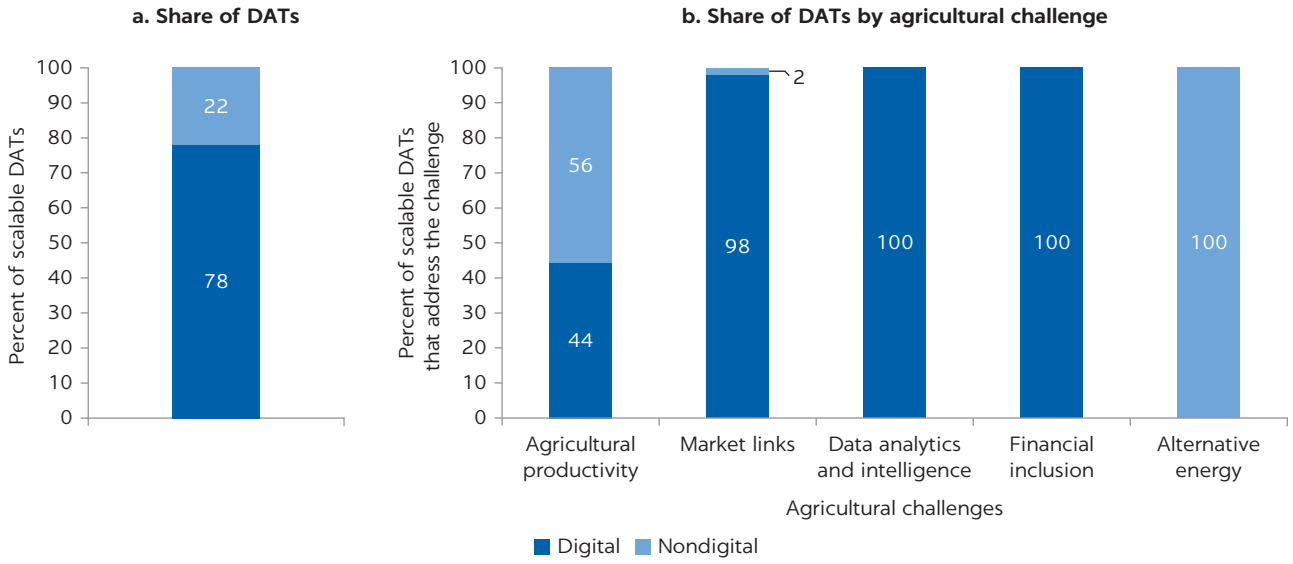
IMPORTANCE OF INVESTING IN THE DIGITAL ECOSYSTEM

More than 75 percent of DATs in the database are digital (panel a of figure 2.3); that is, the primary technology involves a digital solution. For instance, a solar technology irrigation system may have digital components; however, because the primary technology is nondigital (solar technology), it would be classified as a nondigital DAT. An online marketplace would be classified as digital because the primary technology behind the solution is digital.

Based on this classification, DATs addressing market links, data analytics, and financial inclusion challenges are considered digital, whereas those focused on productivity are split between digital and nondigital (panel b of figure 2.3). The nondigital agricultural productivity DATs include those focused on biotechnology or aquaponic or hydroponic systems (or both). Also, those focused on alternative energy are all considered nondigital. The large share of digital DATs demonstrates that, to harness the full potential of DATs, it will be important for the public sector to continue investing in Sub-Saharan Africa's digital ecosystem.

Although more than 75 percent of DATs in the database are digital, agriculture is one of the slowest sectors to adopt digital technologies (McKinsey Global Institute 2015). In addition, Africa's agri-food system is characterized by a large, low-skill, smallholder population in rural areas that has unequal access to technologies, information, and markets. Rural internet penetration is only 10 percent in Africa, and it varies with age, gender, and income

FIGURE 2.3
Digital DATs in Sub-Saharan Africa



Source: DAT database.
Note: Preliminary findings from the stocktaking activity. *N* = 194 in panel a; *N* = 193 in panel b. DATS = disruptive agricultural technologies.

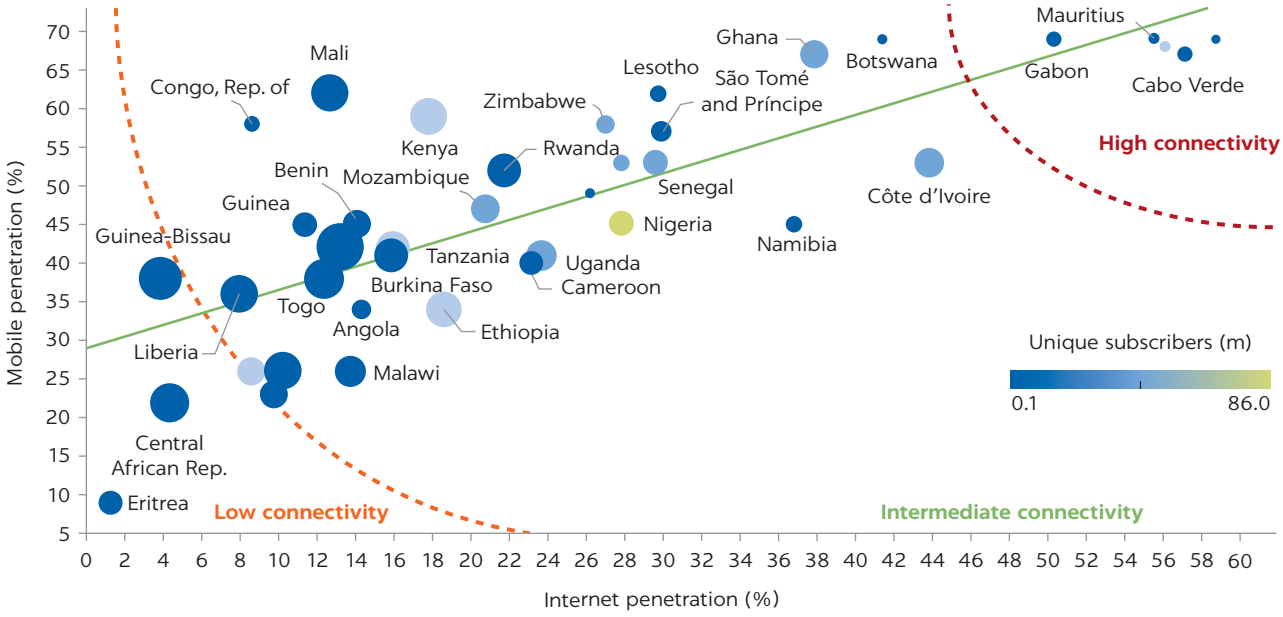
(World Bank 2016). Major lags in the agriculture sector's digital ecosystem pose a potential challenge to DATs that are primarily digital.

In the meantime, entrepreneurs are finding ways to succeed in low-connectivity environments using off-line technologies. Examples in Africa include firms such as Digital Green and Kuza that are using off-line videos to provide extension. To illustrate the digital ecosystem in Africa's agricultural economies, figure 2.4 maps African countries according to mobile penetration, internet penetration (percentage of individuals using the internet), and the agriculture sector's contribution to GDP.

Most African countries have intermediate-level mobile and internet penetration. However, digital accessibility is much lower in rural areas and varies greatly according to age, gender, and income. Therefore, reaching all African farmers with DATs will require a range of tools that can operate in different connectivity scenarios even within a country; for instance, low-connectivity scenarios require nascent technologies, intermediate-connectivity scenarios require transitional technologies, and high-connectivity scenarios require advanced technologies. Technologies for low-connectivity environments include off-line digital solutions such as portable soil testers, SMSs, and interactive voice recordings, along with platforms that work off-line and can upload or receive data when a connection becomes available.[1] Transitional technologies, which can operate in intermediate-connectivity environments, include e-platforms, supply chain tools, and basic precision-agriculture tools. In high-connectivity scenarios (high internet and mobile penetration), real-time monitoring and feedback are possible for advanced technologies such as controlled environment agriculture and farm robotics. Figure 2.5 shows the digital agriculture continuum and accompanying agricultural technologies that can operate in different connectivity scenarios.

FIGURE 2.4

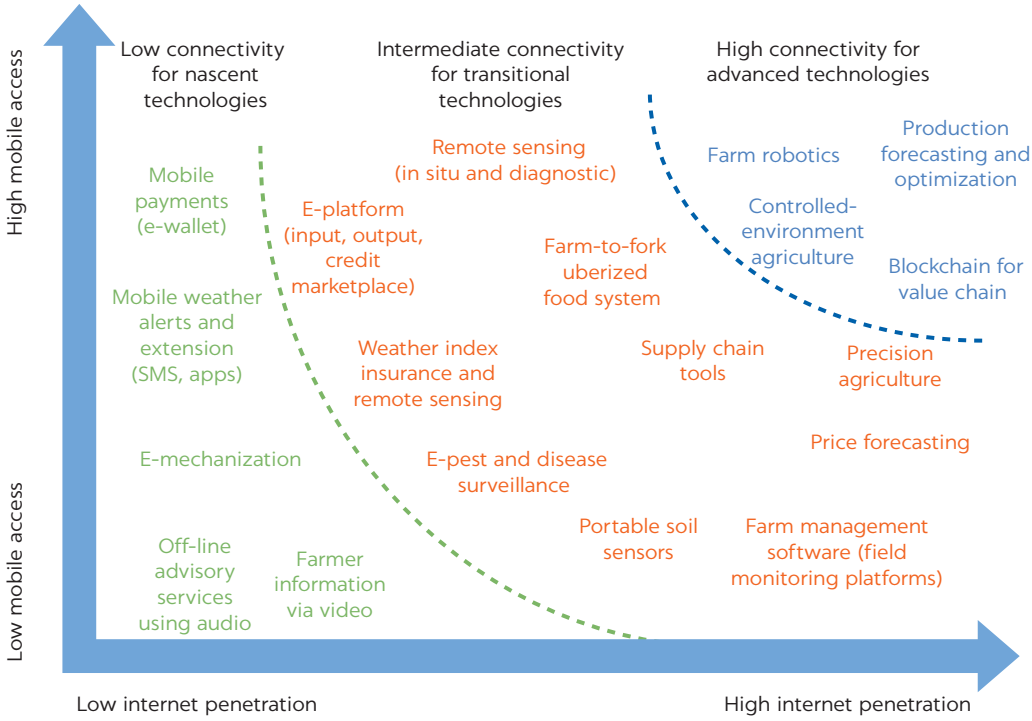
Mobile penetration, internet penetration, and agricultural GDP in Africa



Source: World Bank based on internal data and data from Global System for Mobile Communications Association (GSMA) and the Internet Telecommunication Union.
Note: The size of the country markers (bubbles) corresponds to the magnitude of agricultural gross domestic product (GDP), and the color of the bubble corresponds to the number of unique subscribers in millions. Most African countries have intermediate-level mobile and internet penetration; however, digital accessibility is much lower in rural areas and varies greatly according to age, gender, and income.

FIGURE 2.5

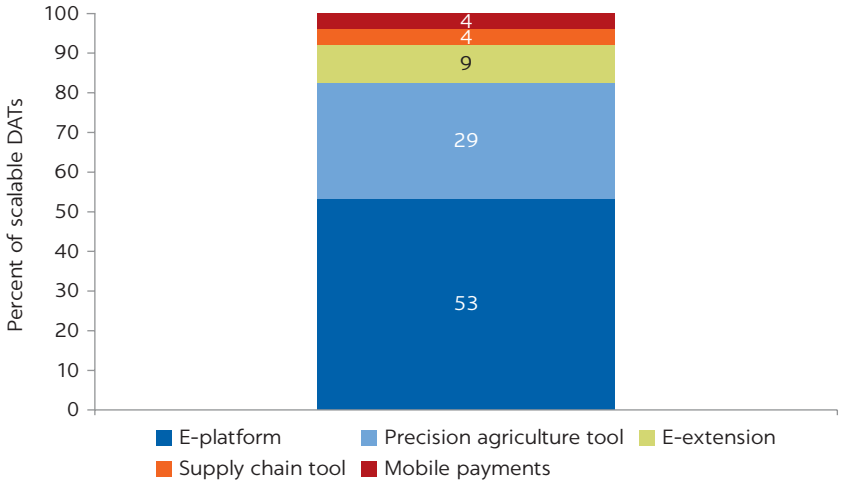
Digital agriculture continuum



Source: DAT database.
Note: DATs operate across a range of connectivity scenarios. DATs = disruptive agricultural technologies; SMS = short message service.

FIGURE 2.6

Digital agricultural technologies using different tools



Source: DAT database.
Note: Preliminary findings from the stocktaking activity. *N* = 151. DATs = disruptive agricultural technologies.

DATs are adapting to the low-connectivity context of African agriculture. When this digital agriculture continuum framework is used on the database of 194 DATs, 83 percent of the DATs are found to be operating as e-platforms or basic precision-agriculture tools (figure 2.6). Technology adaptations are allowing for deeper adoption and penetration of DATs in intermediate-connectivity scenarios. Evolving technology adaptations do not negate the importance of continuous investment in rural digital ecosystems.

Two key conclusions emerge from this analysis of the digital aspects of DATs. First, digital technology is evolving to meet the needs of different connectivity scenarios. Second, continuous investment in the digital ecosystem can further strengthen the impact of digital DATs.

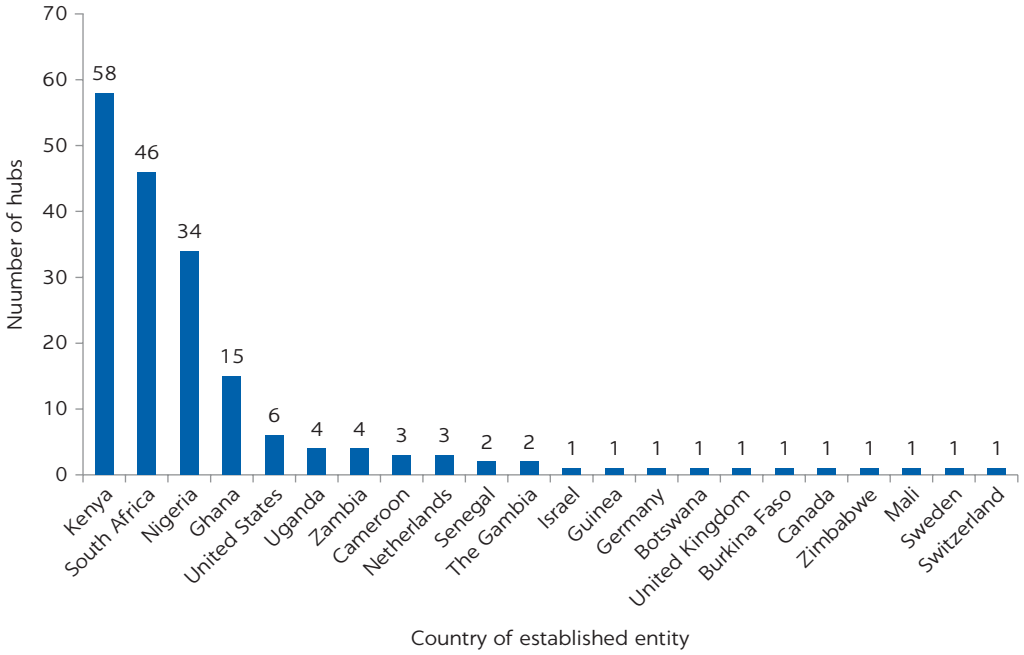
DATs ARE CONCENTRATED IN KENYA, NIGERIA, AND SOUTH AFRICA

Figure 2.7 shows that 75 percent of emerging DATs are concentrated in Kenya, Nigeria, and South Africa. Kenya is a leading agri-technology hub, with 58 DATs operational in the country, followed by South Africa and Nigeria (figure 2.7). Kenya has one of the top-rated digital ecosystems on the continent.[2] The country has the third-largest technology incubation and acceleration hub in the region.[3] Additionally, mobile connectivity and high penetration rates contribute to Kenya's success in the agricultural technology landscape.

Kenya also has some of the highest levels of mobile penetration: 59 percent penetration of unique mobile subscribers in 2017, compared with 44 percent, on average, for the Sub-Saharan Africa region (GSMA 2018a). The country is also characterized by a robust mobile money ecosystem, with more than 70 percent of the population using mobile money regularly (Kenya 2016). The device

FIGURE 2.7

Scalable agri-tech DAT hubs, by country



Source: DAT database.
Note: Preliminary findings from the stocktaking activity. *N* = 188. DAT = disruptive agricultural technology.

penetration rate is deep in rural areas as well, with 30 percent of the rural population owning smartphones and 72 percent owning feature phones, according to a survey conducted by Deloitte in 2016.

POSITIVE INDICATIONS OF DAT ADOPTION IN SUB-SAHARAN AFRICA

Table 2.2 shows the scale of operations measured by the number of farmers served for 15 DATs in Kenya. Such data are sparse. These data were collected through an online survey for the DATs operating primarily in Kenya and indicate engagement with farmers beyond just farmer registration. Some DATs work with the business-to-business model or the business-to-government model, making it difficult to calculate their operating scale because they are only indirectly reaching farmers. Where scale data are available, DATs operate within a wide range, from 1,000 farmers to more than 600,000 farmers. Table 2.2 indicates a significant level of engagement of DATs within the agri-food system. Nonetheless, more data and research are required to measure the exact level of engagement. Another point to note is that DATs often report their farmer coverage for the region rather than for a specific country. The data provided below are reported only for Kenya (wherever available).

Based on the small sample of DATs shown in table 2.2, financial inclusion DATs are among the most widely adopted (with Arifu being the leader of financial knowledge delivery to farmers in Kenya). Financial inclusion is followed by agricultural productivity, with e-extension services such as Precision

TABLE 2.2 Scale of selected DATs, registered farmers

	DAT	DESCRIPTION	NUMBER OF FARMERS ENGAGED	COUNTRY OF OPERATIONS
1	Akengo Kenya Company Limited (Arifu)	Arifu is a digital adviser helping increase access to financial literacy especially among farmers.	600,000	Kenya
2	Digital Green	Digital Green's community video approach amplifies extension providers' effectiveness to improve farmers' livelihoods.	374,979	Ethiopia
3	Precision Agriculture for Development (PAD)	PAD provides farmers with low-cost mobile agronomic advice that is accessible, relevant, and customized to boost yields.	320,000	Kenya
4	Juhudi Kilimo	Juhudi Kilimo provides asset financing, technical assistance, and business training services to farmers and agro businesses in Kenya.	60,000	Kenya
5	CAPTURE Solutions	CAPTURE Solutions offers full transparency and traceability in an agribusiness environment, which enables digital payment as well as advances to farmers, avoiding crippling loans.	60,000	Kenya
6	FarmDrive	FarmDrive provides credit risk assessment of farmers using mobile phone data.	53,000	Kenya
7	AGIN Limited	AGIN Limited provides a platform to help its partners create strategic links to provide services to farmers seamlessly, for example, access to inputs, loans, insurance, farm market, climate and farm information, and advances within the shortest time possible.	40,000	Kenya
8	Agrics Company Limited	Agrics provides agricultural products and services on credit to smallholder farmers to increase production and value chain effectiveness.	18,000	Kenya
9	Tulaa	Tulaa is a mobile lending and commerce platform for rural farmers.	15,000	Kenya
10	Agri-wallet (Dodore)	Dodore has developed a platform called Agri-wallet that enables financial inclusion of all value chain actors around smallholder farmers.	14,538	Kenya
11	Hello Tractor	Hello Tractor connects tractor owners and smallholder farmers in Sub-Saharan Africa through a digital tractor-sharing application.	13,000	Kenya
12	AgroHub	AgroHub is a mobile and web-based agricultural value chain project monitoring, evaluation, data capturing, and reporting management information system.	12,000	Kenya
13	UjuziKilimo	UjuziKilimo provides real-time soil testing services.	10,000	Kenya
14	Agrocares	Agrocares operates as Soilcares Company in Kenya; it launched a product that allows smallholder farmers to easily carry out soil tests before planting to enhance productivity.	10,000	Kenya
15	Farmers Pride Africa	Farmers Pride Africa is a provider of agriculture management services intended to link rural farmers and agro dealer shops. The company's services offer quality inputs and information through a franchise model along with soil testing and farmer insurance, enabling smallholder farmers to access timely and relevant quality inputs at affordable prices.	10,000	Kenya

Agricultural productivity | Market links | Data analytics and intelligence | Financial Inclusion

Source: Online survey.
Note: This list is not exhaustive and only includes responses from the online survey. DATs = disruptive agricultural technologies.

Agriculture for Development and Digital Green. E-extension addressing the agricultural productivity challenge is one of the most common and easily adopted services among farmers. Market links and data analytics and intelligence are not commonly adopted by farmers in Kenya. More in-depth research is required to understand the behavioral preferences for adoption of certain kinds of services.

INVESTMENTS IN AGRI-TECHNOLOGY IN SUB-SAHARAN AFRICA

Access to finance remains a constraint for DATs—68 percent are not receiving any form of formal funding from equity investors or banks. Investments in DATs that do receive formal funding range from US$30,000 in the early rounds of funding to millions of dollars in the later rounds. The key institutional investors in Sub-Saharan Africa are a mix of venture capital and development partners and include the International Finance Corporation (IFC), the Meltwater Foundation, AHL Venture Partners, the Global System for Mobile Communications Association (GSMA), and the US Agency for International Development. Twiga Foods is one of the best-funded DATs in Sub-Saharan Africa, with total investments of US$30 million. The company received capital investment worth US$10 million in November 2018 from the IFC, TLcom, and the Global Agriculture and Food Security Program. Agri-technology investment in Sub-Saharan Africa is a minuscule proportion of investment in the global agriculture technology market. According to AgFunder, private investment in agricultural technologies in 2017 amounted to US$10.1 billion globally (AgFunder 2018). However, Sub-Saharan Africa receives much less than 5 percent of global private investment in agri-technology (Disrupt Africa 2018).

NOTES

1. All digital solutions do not require connectivity. Data require connectivity. Stored data or videos can be used off-line through devices.
2. Kenya is rated number 5 in Africa in the World Bank Digital Adoption Index (2016), number 2 in the *Harvard Business Review* Digital Evolution Index (2017), and number 2 in the region based on the Global Enabling Digitalization Index (2018).
3. In 2018, Kenya was rated third in the Sub-Saharan Africa region based on the number of technology incubators and accelerators, that is, 30 out of the more than 400 tech incubators and accelerators in Africa (Bayen 2018).

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3 Ecosystem Assessment Findings

Chapter 2 shows that disruptive agricultural technologies (DATs) are demonstrating early promise in leapfrogging conventional technologies to reach farmers in Sub-Saharan Africa. Given the potential of DATs to accelerate the impact of solutions to challenges faced by the agri-food system, the innovation ecosystem in Sub-Saharan Africa must be studied to delineate findings that will help accentuate the scaling-up efforts of DATs. Given the concentration of DAT firms in Kenya and Nigeria—together, these two countries account for half of the assembled database—this chapter closely explores the two agriculture innovation ecosystems to unpack the factors that are driving their success in incubating DATs. This analysis uses a mixed-methods approach to examine the bottlenecks preventing both successful and emerging ecosystems from achieving greater scale and agri-food-system–level impacts on the African continent.

Methodologically, the quantitative assessment used in this analysis scored each country's ecosystem along six dimensions: (1) entrepreneurial culture, (2) ecosystem density, (3) access to finance, (4) human capital, (5) infrastructure, and (6) regulatory environment (see appendix B for details). The selected dimensions are drawn from the literature on the characteristics of thriving start-up ecosystems (Isenberg 2011). The infrastructure dimension was added to this assessment to capture the significance of physical and digital connectivity for last-mile delivery, farmer adoption, and impact of DAT solutions in largely rural and remote geographies.

In the literature on innovation ecosystems, the relationships between ecosystem size, performance, and these six dimensions can be summarized as follows:

- *Entrepreneurial culture*. An innovation ecosystem benefits from a culture that encourages risk-taking and collaboration. At the same time it also helps build risk tolerance and provides incentives for collaboration by encouraging firms to embrace disruption, and builds university–private sector links as role models, increasing the demand for teaching entrepreneurial skills.
- *Ecosystem density*. Innovation is a function of the frequency and intensity of engagement between highly skilled innovators. Creating agglomerations of talented human capital in hubs and clusters increases the potential for

successful innovations to emerge. The most famous example of this phenomenon is Silicon Valley, which brings together the best global minds in one of the most innovative technology hubs in the world.

- *Access to finance*. The availability of finance at low interest rates (through micro loans, venture capitalists, public capital markets) is critical for the success of start-ups and small entrepreneurs. Experienced investors also make a difference by coaching and mentoring founders on their journey.
- *Human capital*. The availability of skilled labor is essential to support business growth. A robust innovation ecosystem facilitates investment in human capital to build start-ups and retain a skilled workforce with the competencies required to work in entrepreneurial workplaces. It will also seek to help build businesses and innovate in the future. To kick-start investment in human capital, countries can create flexible labor markets, promote diversity in the workplace, and seek to attract labor with a variety of skills.
- *Infrastructure*. A range of infrastructure support is essential, including telecommunications, transportation, logistics, roads and bridges, storage, and broadband connectivity, as well as last-mile infrastructure.
- *Enabling regulatory framework and incentives*. Governments play a key role in creating a stable, predictable, and supportive regulatory environment for entrepreneurs and investors. Supportive policies may include the ease of starting and closing a business, tax policy, patent protection, formalizing alternative funding models, and investing in research and development.

Both qualitative and quantitative assessments were undertaken for this ecosystem analysis. The quantitative assessment undertaken at the country level captures economy-wide performance indicators that apply to other innovation ecosystems. To derive constraints and challenges specific to the DAT innovation ecosystem, this analysis also undertook a qualitative assessment based on stakeholder interviews with identified ecosystem players from the government, the private sector, and development partners.

KENYA'S AGRICULTURE SECTOR

Agriculture accounts for 26 percent of Kenya's GDP and indirectly contributes an additional 27 percentage points by way of links with other sectors (FAO, n.d.). Furthermore, the sector contributes 65 percent of the country's export earnings and provides a livelihood—employment, income, and food security needs—to more than 80 percent of the Kenyan population. Agriculture is the source of 64 percent of income among the poor; even among the non-poor, the corresponding share is 53 percent (World Bank 2018a).

Historically, growth trends in the agriculture sector have had repercussions for the entire Kenyan economy. When economic growth rebounded to 6.3 percent in 2018 after an eight-year low of 4.9 percent in 2017, the most significant growth acceleration came from agriculture. Because of strong backward and forward links with manufacturing (particularly agro-industries) and the wholesale and retail sectors, agriculture's growth rates are highly correlated with those of other sectors (World Bank 2019c). The Kenyan government has emphasized agriculture's importance by making commitments to transform the sector through the Big Four Agenda[1] and Vision 2030.[2]

Despite agriculture's large economic footprint, its potential to catalyze sustainable development in Kenya remains unrealized because of the growing effects of climate change, exposure to market fluctuations, continued use of outdated farming methods, and the increasingly binding constraint of land availability.[3] These challenges are particularly severe for smallholder farmers, who comprise approximately 80 percent (GeoPoll 2018) of the farming population in Kenya. Most smallholder farmers still use low-quality inputs, rely on human labor for cultivation and harvesting, and lack access to appropriate postharvest storage solutions. Cumulatively, these weaknesses have led to low farm productivity and high postharvest losses, lowering both food security and farm income. If addressed, there is great potential for enhanced food security, secure farmer livelihoods, and overall growth of the country's economy.

Given the scale of challenges faced by Kenyan smallholder farmers, it is evident that technological disruption presents an exciting opportunity for the sector to reach the production-possibilities frontier by optimizing every stage of the agricultural production cycle. From the delivery of pluralistic, data analytics–based advisory services to access to timely credit, affordable farm inputs, and mechanization, to supply of high-quality postharvest services and guaranteed access to solar-powered irrigation kits (photo 3.1) to growing urban markets, it is now evident that DATs are critical for achieving Kenya's vision of the agriculture sector as ensuring food security, securing farm livelihoods, and enhancing overall growth of the country's economy.

PHOTO 3.1

SunCulture's solar-powered irrigation kit

Source: © SunCulture. Reproduced with permission from SunCulture; further permission required for reuse.

KENYA'S DAT INNOVATION ECOSYSTEM

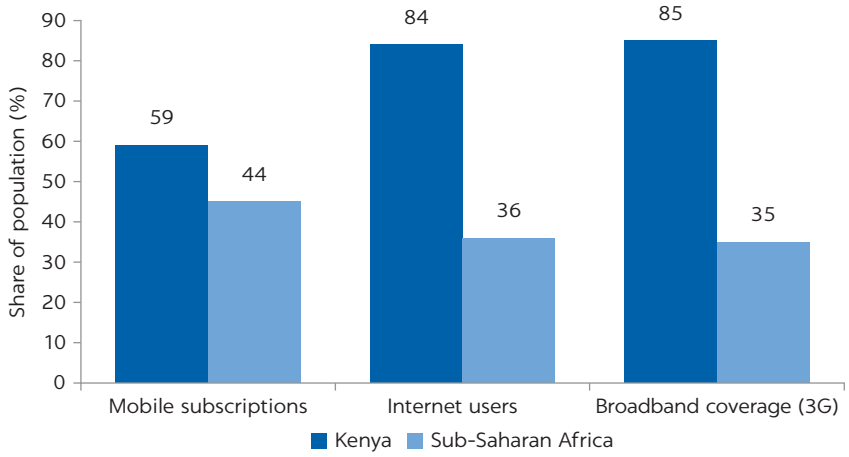
Kenya has one of the most advanced agri-technology ecosystems in Sub-Saharan Africa. Nearly 30 percent of all agri-technology start-ups in Sub-Saharan Africa operate in the country, with 18 percent of all firms also locating their headquarters there (Jumia 2019). Across all of Africa, it ranks fourth in the number of accelerators and incubators (30), after South Africa (59), Nigeria (55), and the Arab Republic of Egypt (34) (Collon and Dème 2019). The quality and potential of Kenyan DATs is reflected in their success in attracting capital in 2018, when the country was one of the top destinations for technology start-up investment in Africa (CTA 2019).

Two of the main drivers of the rapid growth of DATs in the Kenyan market are the high level of mobile phone penetration (figure 3.1) and the widespread use of mobile payment systems (M-Pesa). Kenya has some of the highest levels of mobile phone penetration, with a unique subscriber penetration rate of 59 percent in 2017, compared with 44 percent, on average, for the Sub-Saharan Africa region (GSMA 2018a). Internet connectivity is high, with 84 percent of Kenyans reporting access (Jumia 2019). Additionally, phone-based applications have a growing market, with 3G network coverage growing from 67 percent to 85 percent in the 2014–17 period; today, even 4G coverage is reaching more than a third of the population (GSMA 2019a). The rural-urban digital divide is smaller in Kenya than in several Sub-Saharan Africa countries. About 80 percent of smallholder farmers in Kenya own mobile phones, and more than 15 percent of them own smartphones (McKinsey Global Institute 2015). A robust mobile money ecosystem envelops the country, with more than 70 percent of the population using mobile money regularly (Kenya 2016), compared with the Sub-Saharan Africa average of 48.8 percent.

Nairobi leads the Sub-Saharan Africa region not only in the number of DATs, but also in the dynamism of its innovation ecosystem. At the April 2019 Innovation, Knowledge, and Challenge Conference, DAT challengers competing for the opportunity to join the World Bank's One Million Farmer Initiative showcased a wide range of technology innovations and dynamic

FIGURE 3.1

Kenyan mobile infrastructure and usage, 2018



Sources: GSMA 2019a; Jumia 2019.

business models that are already deployed among Kenyan farmers. Several participating DATs provide farmers with affordable digital solutions that boost agricultural productivity and profitability by providing market matching services (for example, Hello Tractor, DigiCow). Other DATs are engaged in providing affordable advisory services for smallholder farmers, cooperatives, and agribusinesses by providing actionable weather, pest, disease, soil, and market information based on hyper-local, real-time data analytics using farm sensors (for example, UjuziKilimo). A small share of DATs are also harnessing opportunities provided by emerging technologies such as blockchain, the internet of things, artificial intelligence, and drones to disrupt farming and make it more climate resilient, youth friendly, and commercially viable by tailoring solutions to highly specific needs of end users (for example, Astral Aerial).

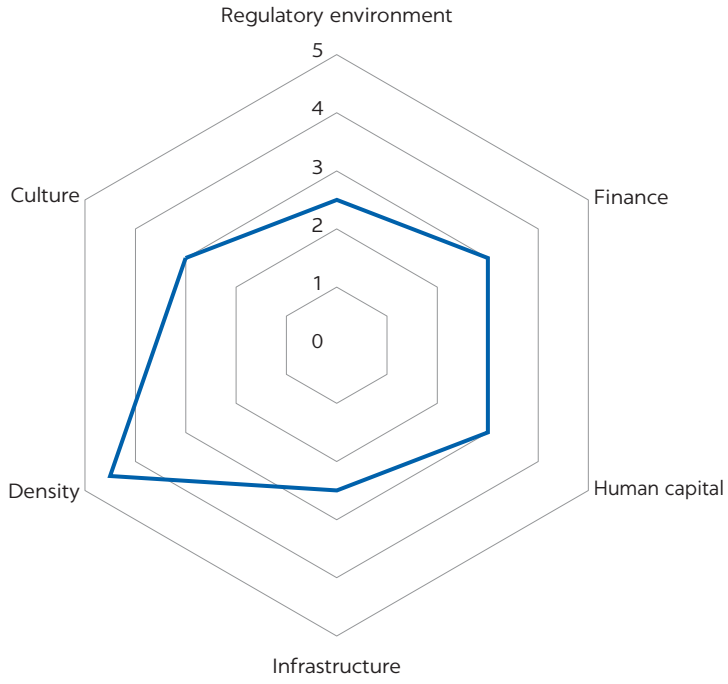
Findings from the quantitative and qualitative assessment

Averaging its scores on the six dimensions selected for this assessment, Kenya's DAT ecosystem scores 3 on a scale of 1–5 (figure 3.2).[4]

The composite score reflects the Kenyan DAT innovation ecosystem's performance on six dimensions (see disaggregated scores in table 3.1). It is evident that the key driver of Kenya's success is ecosystem density. The ecosystem's performance is constrained by the regulatory environment and level of infrastructure. A more detailed analysis of the performance on each dimension is presented next.

FIGURE 3.2

Kenya DAT innovation ecosystem assessment: Aggregate scores



Source: World Bank.

TABLE 3.1 Kenya DAT innovation ecosystem assessment

Aggregate scores and indicators

ENTREPRENEURIAL CULTURE	**3**
Attitudes toward entrepreneurial risk	5
Companies embracing disruptive ideas	4
Entrepreneurial capacity	2
Level of university and industry research collaboration	4
Level of economic freedom	2
DENSITY	**4.5**
Cluster development	4
Presence of technology hubs	5
Multistakeholder collaboration	4
Number of DATs in the country	5
FINANCE	**3**
Equity financing	5
Domestic credit to private sector	2
Financing for agricultural research and development (R&D)	1
Number of equity technology start-up deals in 2018	5
HUMAN CAPITAL	**3**
Extent of digital skills among population	4
Labor market for DATs	3
Future workforce	2
Graduate skill set	3
INFRASTRUCTURE	**2.5**
Availability of transport (roads, rails, air, sea, and access to water transport)	3
Reliability of electricity supply	2
Internet access	5
Mobile phone availability	5
Reliability of water supply	2
REGULATORY ENVIRONMENT	**2.5**
Ease of starting and doing business	2
Patent protection	3
Data protection policies	1
Agricultural regulatory framework	5
Tax-paying environment	3
Strength of investor protection	2
Suitable markets	5

Source: World Bank based on Dalberg stakeholder interviews.
Note: DAT = disruptive agricultural technology.

Entrepreneurial culture

Score: 3

Attitudes toward entrepreneurial risk. Kenyans exhibit a strong entrepreneurial spirit, as reflected by the high score of 5 on this indicator. Many pursue entrepreneurship, either as a primary source of income or as a supplemental source

of income. Some professionals run their own businesses while being employed by others. However, building a scalable company requires a full-time commitment from innovators; in its absence, enterprises often fail to grow beyond their earliest stage.

Companies embracing disruptive ideas. An indicator of the innovation ecosystem's strength is the openness of Kenyan firms to disruptive ideas. As more people focus on scaling up their enterprises and accommodating new ideas, the chance increases that some of these businesses will offer innovative ways to address national issues such as food insecurity.

Entrepreneurial capacity. Conversely, Kenya's low score on this indicator also highlights low entrepreneurial capacity at the country level, reflecting (1) gaps in the education system in embedding entrepreneurship and technology innovation and (2) the systemic need to promote self-employment. Despite low entrepreneurial capacity at the country level, local youth are increasingly choosing full-time entrepreneurship, with 48 percent preferring to venture into entrepreneurship and just 26 percent seeking employment (*Business Daily* 2017).

One of the defining features of Kenya's DAT ecosystem is that it has also successfully attracted international players. During the qualitative assessment, a DAT chief executive officer in Kenya highlighted that many technology companies in the country are run by non-Kenyans who sometimes lack an understanding of the local context and realities.

Level of industry and university research collaboration. Universities in the country increasingly work with the private sector to conduct research, reflecting the government's efforts to allocate more budgetary funding to universities and research organizations. International agencies are increasingly working with local universities to build research capacity. For example, the Japan International Cooperation Agency has partnered with Jomo Kenyatta University of Agriculture and Technology to conduct research within the university (JKUAT 2019). Despite the positive academic research environment, the level of collaboration with local companies in translating this research into innovation is still limited. Promoting research and innovation collaboration across sectors and stakeholder groups—such as academic institutions, government, and the private sector—can unlock access to solutions that meet farmers' needs.

Density

Score: 4.5

Cluster development. The greatest technology start-up density is in and around Nairobi; the same is true for agri-tech. According to Investment Frontier, the city is home to more than 400 start-ups (Rayan 2016). The high ecosystem density can be traced back to the growth and agglomeration of financial technology firms after the launch of M-Pesa in 2007. This innovative mobile phone product provided an attractive base platform upon which other innovative solutions have been built.

Most national government services, investors, business support services, and avenues to market are in Nairobi, contributing to multistakeholder collaboration. A product manager at a leading DAT in the country noted that most innovators are working with fellow innovators and ecosystem enablers, such as AGRA and the Rockefeller Foundation, to reach more farmers. A venture capital investor noted that Nairobi attracts talented entrepreneurs

and investors who choose to live there because it is also a hub for major multilateral organizations such as the United Nations and the World Bank. This has led to the high number of DAT innovations emerging from Nairobi. Ensuring that such solutions are scaled up to reach all Kenyan counties is still required.

Presence of technology hubs. Kenya has a high number of technology hubs, incubators, accelerators, and co-working spaces compared with other countries in the region. According to the International Finance Corporation, the country is ranked fourth in the number of these hubs (IFC 2018). The Africa Incubator Network is also based in Nairobi. These hubs have been beneficial to early stage start-ups because they provide business support services, prototyping assistance, and, where necessary, some very early-stage capital to the innovators. However, despite their prevalence, several innovators reported being unaware of their existence. Hence, they fail to leverage their services. Additionally, most of these hubs have recently begun operating and still provide highly variable quality of service.

A wide array of ecosystem actors in the country provide vast networking opportunities. Some of these actors include for-profit tech companies such as IBM and Google; international and domestic investors such as the Savannah Fund, Emerging Capital Partners, and Impact Amplifier; aspiring Kenyan and foreign entrepreneurs; development partners such as the World Bank, the Omidyar Network, and the Hivos Foundation; social enterprises; public-private partnerships; and others (Ndemo and Weiss 2016).

Multistakeholder collaboration. The density of these several overlapping organizations and networks is an untapped opportunity that can accelerate the scale-up of DATs in Kenya. The large assortment of ecosystem enablers can provide partnership opportunities for access to funding, human capital, and other resources as they seek to scale up their operations. Ever since 2014, the University of Nairobi has convened diverse stakeholders to organize and execute the annual Nairobi Innovation Week. The goal is to support and accelerate the innovation and entrepreneurship ecosystem in the region.[5] The Sankalp Forum has also provided an avenue for innovators to showcase their products and meet possible partners.[6]

Meanwhile, government officials in agriculture have formed caucuses that meet regularly to share ideas and establish partnerships. Additionally, various ecosystem players have taken the initiative to create their own networks across various channels. For instance, several WhatsApp groups have formed along agriculture-focused product lines and innovation types. However, these groups often lack authenticity because most innovators are reportedly not willing to share their stories for fear of competition.

Given the large number of networking resources in the country, more networking can be focused on agri-technology innovations. The World Bank, through the One Million Farmer Initiative, has committed to building the first agri-technology–focused incubator in the region with a base in Nairobi. Other ecosystem players could develop catalytic partnerships to magnify the impact of this and other similar initiatives to ensure that DATs with a minimum viable product and a small user base can reach scale and have an impact on smallholder farmers. Innovators also need to take advantage of collaborative platforms and networking events to build connections with each other and with potential partners.

Finance

Score: 3

Equity financing. In contrast to other technology start-ups, early-stage DATs are constrained by low access to capital. Access to domestic venture capital, private equity, or angel and debt fund investment is extremely low for agri-technology innovators. This constraint has led to reliance on personal funds, sparsely available donor grants, and foreign venture capital.

The East African head of an advisory DAT readily admitted that his company relied on donor funding and grants, reflecting the financing trend for many advisory-only platforms. The government makes capital available through national institutions such as the National Social Security Fund and the National Health Insurance Fund, which could be channeled into the sector. However, such investments have not been prioritized by agri-tech start-ups. Furthermore, most available local funding comes from outside the country. The few local investors have shied away from funding agri-technology innovations because they lack a track record of growth or exits and are therefore viewed as high-risk investments. This makes it difficult to raise follow-on capital once a firm is past the early seed stage, according to the agribusiness sector lead of a locally based development institution that runs a challenge fund to invest in early-stage agri-technology companies.

Relative to other tech start-ups, DATs are also hampered by limited skills and lower access to the networks required to raise capital. Agri-tech start-ups increasingly need to become investor ready by building strong teams and business models and developing the internal structures and capacity required to accommodate such funding.

Lastly, the limited availability of affordable debt is a key constraint for DATs in the agri-finance field. As businesses grow, they increasingly need fairly priced debt financing that can adequately fund operations, as well as be used for on-lending. For DATs focused on financial inclusion for farmers, having the technical know-how to structure financing instruments—such as special purpose vehicles to access capital from a wide variety of investors—could help increase their reach (figure 3.3). Finally, access to first-loss capital is essential to help DAT innovation scale up. Also, blended finance models can use public and social impact capital to catalyze private investments.

Domestic credit to private sector. As of 2018, 19 million Kenyans had active mobile loans (CryptoDavid 2019). Mobile phone applications have simplified access to credit history, and that data can now be collected online through the loan application. Bolstered by this mobile payment and mobile lending infrastructure, many DATs in Kenya provide their services to farmers with embedded mobile payment and credit plans. Of the 23 DAT start-ups that participated in the Innovation, Knowledge, and Challenge Conference held in Kenya, the ones offering the most sophisticated and mature solutions bundled agricultural, advisory, and extension services, and input supply, with financial, credit, and payment services for market access through mobile devices.

Financing for agricultural research and development (R&D). The Kenyan government's agriculture R&D funding has been relatively low, at approximately 0.8 percent of the total government budget. In contrast, a country such as Mauritius allocates 5.8 percent of its budget to these efforts (Beintema and

Stads 2017). Given the scale of agricultural needs and challenges, Kenya's allocation suggests an underinvestment. Therefore, the government has been drafting policies and frameworks, such as the establishment of a national research fund, that could ensure adherence to the African Union's protocol that obliges member states to commit a minimum of 1 percent of GDP to support scientific research (Kenya 2014). The government also has the opportunity to partner with private sector entities that could support research initiatives and ensure that more funds are channeled into the sector.

Number of equity technology start-up deals in 2018. An assessment of equity funding flows and the number of deals in the ecosystem placed Kenya ahead of its Sub-Saharan African counterparts. In 2018, Kenyan start-ups took the lead in attracting US$348 million in equity funding across 44 deals. This constituted a 136 percent increase from the previous year (Collon and Dème 2019), with a portion of the investment going to the agri-technology market.

Human capital

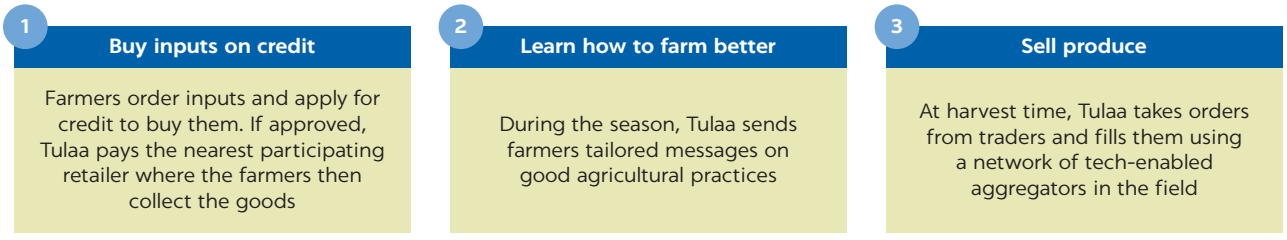
Score: 3

Extent of digital skills among population. Kenya has a larger and more high-quality pool of talent for DATs relative to other Sub-Saharan African countries. Digital literacy among the Kenyan population is high, which has made it comparatively easier for DATs to find customers in rural markets that quickly understand the solution. On the other hand, DATs struggle with customer adoption because of low technology use among their end users (older, less technology-literate smallholder farmers), requiring them to allocate additional resources to building solution awareness.

Labor market for DATs. Up to 30 percent of employers in Kenya cite the inadequately skilled workforce as a major constraint to business expansion (Wakiaga, n.d.). Several DAT innovators attribute the skills gap to a lack of formal internship structures and pre-college work exposure, and to the failure to teach students problem-solving skills. Others have also noted the short supply of data scientists and software engineers as a barrier to their development. Consequently, DATs have focused their recruitment strategies on hiring people with technical knowledge and experience in the agriculture sector as well as other engineering sectors. Because most DATs are still in the early stages, they require employees who can play versatile roles cutting across leadership skills, agriculture experience, or interest

FIGURE 3.3

Examples of Tulaa's bundling of financing and marketplace services



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in serving smallholder farmers, and strong technology and business competencies. Currently, the education system is producing too few workers with this combination of skills and core competencies. Reflecting on these weaknesses in the labor market, the East African head of a DAT company said, "The universities have graduates with generic, old-fashioned information and we need to fine-tune them to adapt to the modern market."

The gaps in Kenya's labor market are enabling the entrance of human capital from more mature DAT ecosystems, with a score of 3 out of 5. Incoming entrepreneurs and employees bring valuable skill sets and relevant experience to DAT innovations. Foreigners also play leading roles in supporting institutional development, for example, by acting as managers of incubators, mentors at educational facilities, or venture fund managers (Ndemo and Weiss 2016). It would therefore be advantageous for the government to strengthen existing laws to attract more talent. However, a product manager at a Kenyan DAT company also noted that DATs should take more ownership of training and promoting local talent and not just rely on foreign talent.

Future workforce. To address these gaps, the government has been upgrading curricula, expanding coverage, and placing additional focus on technical and vocational education and training. Consequently, Kenya was home to 11 national polytechnic institutions and 125 technical and vocational colleges in 2018, with 67 technical vocational centers under development (Oxford Business Group, n.d.). However, whether this supply increase is fortified by the inclusion of entrepreneurship training, independent projects, and case studies in revised curricula customized to entrepreneurship and innovation remains to be seen. In line with Kenya's Vision 2030 and the new Kenyan constitution promulgated in 2010, the president has also championed the 2017 National Policy on Curriculum Reforms, which has led to the introduction of a new school system that focuses on the global shift toward education programs that encourage optimal human capital development.

Graduate skill set. Despite high digital literacy, specific skill gaps within the graduate pool need to be filled to increase the availability of affordable, skilled labor that is adequately trained to meet the needs of early-stage tech companies. This scarcity of highly skilled talent in most university graduates drives up demand and makes qualified candidates less affordable for DATs, thus slowing down the rate of innovation and scale-up.

Infrastructure

Score: 2.5

Kenya has an average ranking, with a score of 2.5 out of 5 for infrastructure. Since infrastructure quality is worse in rural areas, the ability of DATs to reach farmers is particularly constrained by the low performance on this dimension. Adequate and well-functioning transport infrastructure reduces the cost of input delivery, food storage, and farm-to-market transport. In this context, energy infrastructure supports the development of agri-industries. Information infrastructure enhances the timely transfer of information to farmers and agri-businesses, as well as between producers and markets. Water infrastructure—a precondition for irrigation and water-based power generation—is key to the provision of adequate and affordable power for Africa. The review analyzed innovation ecosystems based on transport infrastructure

(roads, rail, and air), electrification rates, mobile phone availability, internet access, and reliability of water supply.

Availability of transport. Kenya maintains a well-developed transport infrastructure, with an average score of 3. This score is indicative of the country's efforts to ensure the availability and high quality of transportation networks for the entire population, including rural farmers. Kenya is the gateway to East Africa, with three seaports and four international airports. Additionally, the Kenya Railways Corporation is currently developing a standard gauge railway that can connect Kenya, Uganda, South Sudan, and Rwanda (International Trade Center, n.d.). The government is also implementing the Lamu Port and South Sudan Ethiopia Transport Project.[7] This project will open yet another corridor for trade. Finally, the Kenya Rural Roads Authority continues to invest in building the necessary networks for last-mile delivery in the rural areas where most smallholder farmers are located.

Despite the enabling infrastructure conducive to scaling up DATs in Kenya, gaps remain. DAT innovators who deliver physical inputs require last-mile delivery. Most partner with logistics operators and use other ad hoc solutions to reach rural smallholder farmers. Many DATs interviewed provide inputs or aggregate harvests from farmers. They highlighted the need to build internal logistics capacity given that there are few affordable and reliable options in the market. For example, a product manager at a Kenyan DAT company noted that the logistics of transporting a large unit can be cumbersome, with last-mile delivery still a challenge. More resources must be allocated to ensure access to rural populations. Better monitoring of infrastructure project implementation would help ensure quality. Finally, many innovators face challenges in prototyping their products because of a lack of necessary manufacturing facilities in the country. This points to an opportunity for investment in building facilities where innovators can build, test, and manufacture their products locally.

Internet access and mobile phone availability. The telecommunications industry has been crucial to the development of many DATs. Kenya has a very high mobile penetration rate compared with its peers in Africa, with a score of 5. DAT solutions increasingly rely on mobile technology and internet connectivity to access farmers. Kenyan farmers are responding and are using these solutions. More than 80 percent of smallholder farmers own or have access to mobile phones in Kenya (CTA 2019). To increase internet connectivity in rural areas, numerous competitors are rolling out national and metropolitan fiber backbone networks and wireless access networks. In 2018, the number of fiber broadband connections increased by 94 percent (BuddeComm 2019). Information and communication technology– (ICT-) related reforms, such as increasing broadband connectivity and access, have led to Kenya having one of the fastest internet speeds in Africa.

Widespread networks and increasingly affordable mobile data have enabled a surge in the uptake of mobile solutions. In the agriculture sector, the demand for DAT solutions that are offered through feature phones is very high, and most farmers prefer basic solutions that can be more easily understood. Therefore, DATs need to create basic solutions that are accessible, and they will have to train farmers in the use of these solutions. The government of Kenya, for its part, has commenced a comprehensive farmer registration exercise to lay the digital foundation for a simple electronic voucher system for

fertilizer subsidies. It has also piloted the e-voucher system with more than 20,000 farmers in multiple counties in the country (World Bank 2019b).

Reliability of water supply. Kenya performs well on the water indicators compared with other global economies, as reviewed in World Bank (2017). This illustrates how challenges identified in a country's water resources can drive the adoption of a strong legal framework for water management and use. Recognizing the rapidly growing demand and overexploitation of its water resources, Kenya initiated a series of legal and regulatory reforms in 2002. Thus, it adopted a new Water Act and other supporting regulations that upgraded and repealed outdated legislation (World Bank 2017).

Regulatory environment

Score: 3

An assessment of the regulatory environment in Kenya shows that it has an average ranking, with a score of 3. This rank could be attributed to the government's commitment to develop and implement policies, strategies, and regulations to guide production and investment in the agriculture sector.

Ease of starting and doing business. According to the World Bank (2017), Kenya enjoys strong agricultural practices and policies. These include nondiscriminatory practices that assist domestic, foreign, and small-scale private sector operators in doing business, as well as efforts that promote women's participation in agricultural activities. However, Kenya ranks below average globally regarding the ease of starting a business. For existing businesses, taxes are fairly accommodating, as indicated by the tax-paying environment score of 3. The government is now instituting measures to reduce the burden of paying taxes from 25 steps to 14 steps (*Business Daily* 2018b).

Patent protection. Meanwhile, a review of existing patent protection found Kenya to be satisfactory regarding the development of new innovations. The country has at least eight international treaties and organizations governing intellectual property (Institute of Economic Affairs 2011). Additionally, significant effort has been made toward implementation of reforms that create an attractive environment for ease of starting a business and direct foreign investment in the sector. For example, one ecosystem enabler believes that there are no heavy regulations on foreign loans and investments, as in Zimbabwe and Ethiopia. However, although adequate policies are in place to protect investor interests, the country still lags behind others in enacting policies related to data privacy and sharing.

Data protection policies. As DATs scale up and offer more innovative solutions, their needs for data access and sharing frameworks also increase. However, Kenya ranks very low on data protection policies, with a score of 1. At the time of this study, the country had neither enacted legislation nor ratified any conventions on personal data protection. This gap was noted as a point of concern by many DAT start-ups that collect farmer data, and the start-up owners did not know what to expect in the future.

In 2018, the parliament passed the Computer Misuse and Cybercrimes Act, 2018, which is more of a penal law aimed at cybercrime than a substantive law that addresses personal data protection (*Business Daily* 2018a). Nonetheless, there has been momentum. The African Union adopted the African Union Convention on Cyber Security and Personal Data Protection. The Kenyan

government recently enacted the Data Protection Act of 2019, which is in accordance with the convention. This will be a first step toward data protection.

The government has several opportunities to address gaps in the regulatory and policy frameworks. DATs in Kenya would welcome the creation of a legal framework for the digital marketplace. For example, through the marketplace, farmers could upload their data and select the privacy terms. The data could then be made available to the ecosystem players to the extent desired by the farmer. In the long term, one central database would reduce data-collection costs for most ecosystem players. In addition, there is an opportunity to create awareness among the various ecosystem players of the existing regulatory frameworks. This is especially critical for smallholder farmers, who are mostly not aware of their data-sharing rights.

For innovators, a new legal framework will mean understanding and complying with the policies that are relevant to their businesses. Furthermore, unique digital identifications (IDs) can enhance the growth of e-commerce (World Bank 2018b). In this regard, the government has amended the Registration of Persons Act, allowing for the establishment of a National Integrated Identity Management System. The aim is to create, manage, and operate a national population register and to assign a unique national (digital) identification number to every person enrolled in the register (World Bank 2019b).

Agricultural regulatory framework. Kenyan agricultural markets scored just 1 out of 5, largely due to the regulatory obstacles faced by agribusinesses in the production, marketing, and exporting of agricultural products, as well as on the strength of plant protection measures. In particular, the amount of time and paperwork required to export produce is substantial. However, the government of Kenya has taken steps to reform and improve the export process. It has recently reduced the official fees for phytosanitary certification, and has abolished the requirement to obtain an export release order and to pay a per-shipment tea levy to the Tea Directorate (World Bank 2017).

The government has also recently committed to the development and implementation of new policies, strategies, and regulations to attract private investment in the agriculture sector. For example, it has launched the Agricultural Sector Transformation and Growth Strategy and is in the process of finalizing the Hides, Skins, and Leather Development Strategy to enhance investment in the industry.

However, DATs continue to face policy-related challenges despite the government's prioritization of the agriculture sector. Specific policies that enable agricultural innovations to scale up are lacking. Furthermore, limited effort has been made to alert DATs and smallholder farmers about the scope and application of those policies that do exist, leading to their misinterpretation and inconsistent application by various agricultural ecosystem players. For example, in 2017 the Kenyan government banned the use of plastic bags in the country, but it provided inadequate explanatory resources for sensitizing the public to the issue. This affected the operations of a DAT that provides tree seedlings to farmers and requires the use of plastic bags to grow the seedlings. Thus, the population lacked vital information concerning the application of and reasoning behind the law. Even when regulations are clearly outlined and commonly known, agencies responsible for their implementation fail to consistently apply them across the different players in the economy. Such opacity and inconsistency negatively affect all ecosystem players.

LESSONS LEARNED IN KENYA

- *Cellphones and a mobile money platform have driven technology innovation.* Kenya has led the world in mobile money adoption since the launch of M-Pesa in 2007, which has served as a foundation for other innovations to emerge, including in agriculture. Most of the DAT innovators interviewed in Kenya cited the advanced digital environment as a key reason for choosing to establish their businesses in Kenya.
- *Kenya's business-friendly environment has enabled the emergence of innovation clusters and ecosystems.* Ranked third in Sub-Saharan Africa on the World Bank's *Ease of Doing Business 2019*, Kenya's regulatory environment has been accommodating to disruptive models in several sectors. The government has frequently implemented beneficial legislation that does not stifle growth. The vibrant digital- and business-enabling environment has led to a virtuous cycle, whereby more DATs are attracted to the country given its existing technology clusters. The density of DAT attracts even more domestic and foreign DAT innovators and supporting actors, which continue to push Kenya ahead of other countries.
- *Kenya is a top destination for impact investment capital* from donors, the private sector, and philanthropic investors, which has enabled social entrepreneurs, development partners, and governments to pilot new ideas and programs in the country. For example, Mercy Corps' AgriFin Accelerate program has been an anchor partner for the DigiFarm platform, providing funding, knowledge, and networking opportunities for partnership formation.[8] In addition, venture funds have emerged that focus on investing in early-stage technology innovations with a positive social impact, such as Novastar Ventures, Safaricom Spark Venture Fund, and Village Capital.
- *The existence of impact capital has supported the emergence of innovative models* that have the potential to improve the lives of smallholder farmers, models that would otherwise be deemed high risk. This has allowed DAT companies to build and test their solutions in the markets. However, this type of impact-driven, patient capital is limited. Therefore, only a few select DATs have had the privilege of testing and refining their solutions without having to rely on revenue generation for short-term sustainability.
- *Several bottlenecks still constrain the ability of Kenyan DATs to scale up, cover smallholder farmers in all counties, and reach commercial sustainability.* The country fairs well but does not excel on several indicators that comprise some dimensions of culture, infrastructure, the regulatory environment, and human capital. For example, in the domain of culture, a good, strong entrepreneurial spirit contributes to the emergence of many DAT innovations. However, the lack of commitment from entrepreneurs, coupled with limited support for professional growth, hampers these start-ups from making the transition to successful ventures. In the domain of infrastructure, excellent penetration of mobile phones and smartphones provides a large base of farmers who can be reached with DAT solutions. In addition, fair transport networks provide a basis for building distribution networks. However, underdeveloped last-mile distribution and an underdeveloped manufacturing industry increase the cost of operations, thereby impeding rapid scaling.
- *Platform collaboration between the various DAT stakeholders can boost the growth of Kenya's DAT innovation ecosystem.* Platforms help avoid duplication

of effort, support investments into data public goods, and lead to the emergence of more bundled services, which have been shown to have a greater impact on farmers' incomes and yields. Partnerships between innovators, agribusinesses, governments, and development institutions can help build more inclusive, impactful, and sustainable solutions. Additionally, collaboration can support the development of policies that protect users, build trust, and promote investor confidence.

NIGERIA'S AGRICULTURE SECTOR

Agriculture contributes 21 percent of Nigeria's GDP, second only to the services sector, and employs 37 percent of the labor force.[9,10] However, Nigeria still experiences a trade deficit with agricultural products, which comprise 9.27 percent of total imports compared with just 1.25 percent of total exports (Nigeria 2018). To close this gap while also moving the economy away from extractive industries, the government has strategically emphasized the achievement of agriculture and food security, along with greater industrialization by focusing on small and medium enterprises (Nigeria 2016).

The targets for agricultural GDP growth were 5.03 percent in 2017, 7.04 percent in 2018, 7.23 percent in 2019, and 8.37 percent in 2020. However, the sector grew by 3.45 percent in 2017, thus missing the Economic Recovery and Growth Plan target by 1.58 percentage points. Other targets for agriculture are (1) increasing agricultural GDP at an average annual growth rate of 6.92 percent (2017–20), (2) significantly reducing food imports and becoming a net exporter of key agricultural commodities, and (3) becoming self-sufficient in tomato paste in 2017, rice by 2018, and wheat by 2020 (Nigeria 2017).

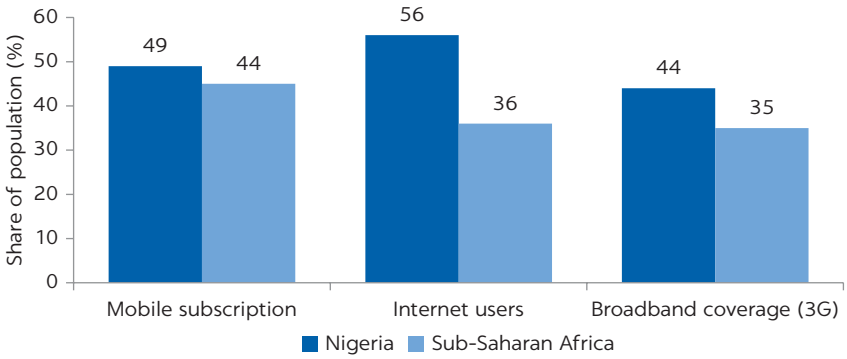
NIGERIA'S DAT INNOVATION ECOSYSTEM

Nigeria has emerged as one of the top digital ecosystems in Africa, and its technology innovation landscape continues to evolve. Multiple digital indexes rank Nigeria near the top. It placed third across Sub-Saharan Africa in both the 2018 Enabling Digitalization Index (Euler Hermes 2018) and the *Harvard Business Review* 2017 Digital Evolution Index (Chakravorti and Chaturvedi 2017). In 2018, 49 percent of the population (97.5 million people) owned mobile phones (GSMA 2019c), slightly higher than the 45 percent mobile penetration rate in Sub-Saharan Africa. Internet users are also on the rise, standing at 56 percent of the population as of 2018 (Jumia 2019). The majority of Nigerians achieve connectivity through mobile internet services (figure 3.4). Although most Nigerian residents (96 percent) still heavily rely on 2G and 3G network coverage (GSMA 2019b), a Deloitte study finds that 57 percent of people surveyed were satisfied with their internet speed (Deloitte 2016).

As Nigerians continue to adopt technology and as digital payment solutions such as Interswitch and Paystack emerge, more people are using mobile money. Mobile money accounts are now owned by 40 percent of adults (GSMA 2019c). This number will likely increase with the improved licensing and regulation guidelines proposed by the Central Bank of Nigeria in 2018. Thus, by leveraging

FIGURE 3.4

Comparative overview of Nigeria's performance on digital adoption



Sources: GSMA 2019b; Jumia 2019.

the expansion of mobile phones, innovators can design DAT solutions for a broader user base than was previously attainable.

Technology hubs and access to capital are also playing a role in fostering DAT innovation in Nigeria. Technology hubs are increasingly important in the country as innovators leverage their services and networks to increase their chances of success in the market. Additionally, Nigeria has the second-highest number of technology incubators and accelerators (55) in Sub-Saharan Africa, after South Africa (59) (Bayen 2018). With regard to capital flows, Nigeria ranked second for technology start-up investments in Africa (behind Kenya), after having received US$306 million across 26 deals in 2018 (Collon and Dème 2019).

DAT innovations have allowed smallholder farmers to access a range of benefits to improve their operations. Smallholder farmers, who constitute 88 percent of the farming population in Nigeria (FAO 2018), play a vital role in the transformation of the agriculture sector. As their mobile ownership rises, more smallholder farmers can access and use DAT innovations. A study conducted by Ogbeide and Ele (2017) finds that 30 percent of smallholder farmers in Cross River State used their phones to access market information, and 22 percent used them for financial transactions.

By harnessing DAT innovations, smallholder farmers in Nigeria have recognized several advantages: reduced travel time; lower cost of doing business; increased collective action through stronger farmer networks; quicker access to price, market, and farming information; increased adaptability to situational changes; and greater farmer leverage during negotiations with wholesalers, traders, and transport providers (Ogbeide and Ele 2017).

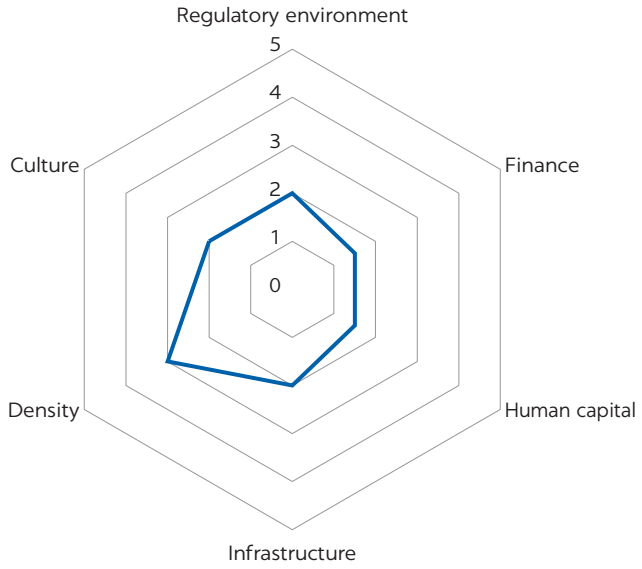
DAT innovators grapple with a host of challenges that are making it increasingly difficult for players to achieve scale. The three biggest challenges affecting DATs are limited access to capital, inadequate and low-quality infrastructure, and unfavorable policies and regulations. Many DATs lack the seed funding they need because investors view them as high risk and would prefer to provide funding only after the solution has been tested in the market and has attracted other investors. In addition, poor infrastructure (unstable power supply, low internet connectivity, and insufficient road networks) disrupts DAT operations and accounts for a large proportion of operating costs. Finally, Nigeria's DAT regulatory environment lacks tailored policies

that clearly consider business needs at the start-up phase. These factors, as well as others (discussed in the next section), slow the growth of DATs as they struggle to establish themselves in the market.

Despite increasing support for DAT innovation, Nigeria still experiences multiple growth-inhibiting gaps in the macro environment (figure 3.5). This is the case across all six assessment areas, yielding an aggregate score of 2, compared with Kenya's score of 3, on a 5-point scale (table 3.2). Nigeria scored highest on the density dimension, driven by the strong presence of technology hubs in the country that are working to upskill DATs and arm them with adequate resources. Conversely, the country ranked lowest in human capital, achieving only a 1 in three out of the four indicators. Despite these scores, Nigeria still demonstrates the potential to make great strides in the agri-technology sector over the coming years. These results, as well as the challenges and opportunities they present, are explored in more depth in subsequent sections.

FIGURE 3.5

Nigeria DAT innovation ecosystem assessment: Aggregate scores



Source: World Bank.
Note: DAT = disruptive agricultural technology.

TABLE 3.2 **Nigeria DAT innovation ecosystem assessment**

Aggregate scores and indicators

ENTREPRENEURIAL CULTURE	2
Attitudes toward entrepreneurial risk	5
Companies embracing disruptive ideas	3
Entrepreneurial capacity	2
Level of university and industry research collaboration	1
Level of economic freedom	2

continued

TABLE 3.2, *continued*

DENSITY	**3**
Cluster development	2
Presence of technology hubs	5
Multistakeholder collaboration	1
Number of DATs in the country	4
FINANCE	**1.5**
Equity financing	1
Domestic credit to private sector	1
Financing for agricultural research and development (R&D)	1
Number of equity technology start-up deals in 2018	3
HUMAN CAPITAL	**1.5**
Extent of digital skills among population	1
Labor market for DATs	3
Future workforce	1
Graduate skill set	1
INFRASTRUCTURE	**2**
Availability of transport (roads, rail, air, sea, and access to water transport)	1
Reliability of electricity supply	1
Internet access	2
Mobile phone availability	4
Reliability of water supply	1
REGULATORY ENVIRONMENT	**2**
Ease of starting and doing business	2
Patent protection	1
Data protection policies	1
Agricultural regulatory framework	4
Tax-paying environment	1
Strength of investor protection	4
Suitable markets	2

Source: World Bank based on Dalberg stakeholder interviews.
Note: DAT = disruptive agricultural technology.

Entrepreneurial culture

Score: 2

A review of Nigeria's entrepreneurship and innovation culture reveals gaps in research collaboration, promotion of entrepreneurial capacity and activity, and economic freedom.

Attitudes toward entrepreneurial risk. Many Nigerians pursue entrepreneurship, as highlighted by the proliferation of micro, small, and medium enterprises (MSMEs) in the country. MSMEs contributed 48.47 percent of Nigeria's GDP in 2013 (Nigeria 2013). Entrepreneurship in Nigeria is primarily driven by people's desires to generate additional income, as well as by the inadequate supply of formal jobs for graduates (Ojo and Oluwatayo 2015). However, unfavorable perceptions constrain entrepreneurship in agriculture. For example, a negative perception persists that agriculture cannot suffice as a primary career. This perception is due, in part, to a lack of successful role models. Furthermore, given

that many start-ups fail within the first two years of operations, entrepreneurship is often considered a high-risk career choice. This constraint is exacerbated by a high poverty rate that drives Nigerians to look for "safer" long-term and sustainable career options.

Entrepreneurial capacity. Risk perceptions are often coupled with inaccurate perceptions of returns to entrepreneurial activity, leading graduates to view working for DAT entrepreneurs as having lower payoffs, and thus being less desirable. One DAT innovator said that "many graduates prefer to work for big companies instead of startups because of the lower pay scale. They do not consider the growth potential of the firm in making their decision." Until start-ups are seen as a valuable and viable career option, many great DAT ideas will remain un- or underdeveloped as potential entrepreneurs and employees seek jobs elsewhere.

Level of university and industry research collaboration. Limited collaboration between universities (which conduct 55 percent of agriculture research in the country; Beintema and Stads 2017) and other stakeholders, such as the government and the private sector, hampers the opportunities to translate research into innovative solutions that address farmers' needs. Instead of leveraging agricultural research institutions in Nigeria, many DAT innovators have opted to carry out their own research.[11] According to a DAT founder that focuses on data analytics and intelligence, "There is not a single database in Nigeria that is focused on smallholder farmers...[ecosystem stakeholders] would rather collect data themselves if they are working on a project [rather] than utilize existing data." More mechanisms for coordination should be put in place to foster knowledge sharing in the agri-technology space.

Density

Score: 3

Cluster development. The demand for training services and market-supportive resources is driving the rapid growth of incubator, accelerator, and co-working spaces. An increasing number of Nigerian technology hubs are narrowing their focus to strengthen the services they provide to entrepreneurs in specific sectors (IFC 2018). Although innovation hub specialization is increasing, not enough spaces focus on agri-technology. Innovation hubs foster a range of transferable skills that can be applied to agri-technology, but they are unlikely to possess in-depth knowledge about the sector or the needs of farmers. This means that incubators and accelerators might guide DATs toward solutions and business models that are not market-facing, thereby reducing their chances of success. Unspecialized co-working spaces also pose problems for DATs. Such spaces tend to host a range of businesses that operate in silos across unrelated industries. This environment inhibits DATs' ability to meet and collaborate with one another because the chance that multiple DAT innovators will happen to work in the same facility is reduced. As noted by the founder of a geospatial database of farms and farmers in Nigeria, the development of a hub to support agriculture-specific technology is necessary.

Presence of technology hubs. An assessment of Nigeria's network density reveals that it excels in the presence of technology hubs but falls short in cluster development across the country. As noted earlier, Nigeria has the second-strongest technology hub ecosystem in Sub-Saharan Africa, after South Africa (box 3.1). The majority (63 percent) of start-up ventures in

BOX 3.1

Wennovation Hub

Wennovation Hub is a not-for-profit innovation hub focused on social impact sectors such as agriculture, health care, clean energy, education, and social infrastructure. Wennovation Hub currently has four campuses located in different areas across Nigeria that each serves a variety of purposes. Current locations include Abuja, Ibadan, Kaduna, and Lagos. The Ibadan campus focuses on pre-incubation programs, working with innovators who have business ideas to ensure that they are equipped with the right skill sets to start their innovations. The Abuja campus focuses on incubation programs, whereby supportive services are provided to start-ups to help them progress from proven concept to market entry. These programs are aimed at aiding such start-ups to increase their revenues and customer bases. Meanwhile, the Lagos campus focuses exclusively on acceleration, working with advanced start-ups. The Kaduna location is centered on societal challenges and providing solutions to the government. The hub also provides direct investments to growth-stage start-ups in their portfolio. It also offers pre-incubation services in the form of infrastructure services and support from a product development team.

The Ibadan campus is focused on agriculture and offers pre-incubation and incubation services to innovative start-ups targeting the sector. Strategically, this location is near many tertiary institutions, such as the University of Ibadan, with which it has a partnership. Through its partnerships and proximity to universities, Wennovation Hub can identity promising solutions for the agriculture sector formulated by students and professors. They have a campus-to-market model based on this premise. Wennovation Hub has supported several DAT start-ups, including Crop2Cash, Green Maples Agro-Allied Ventures, and Afrimash.

Nigeria are headquartered in Lagos or Abuja (VC4A 2018). Although a large proportion of DATs choose to have offices in these cities, many recognize the value generated by working near the smallholder farmers they serve. As such, they maintain core operations in rural areas. Other agri-technology clusters in the country include Enugu, Ibadan, and Kaduna. These communities continue to cultivate ideas and host a moderate presence of DAT start-ups. Nonetheless, such clusters receive significantly less support compared with clusters in Lagos and Abuja. A Venture Capital for Agriculture (VC4A) study finds that most ecosystem-building companies are based in Lagos (156) and Abuja (46), with other cities such as Aba, Ibadan, and Kaduna lagging (VC4A 2018). Without the distribution of related supportive services, DAT start-up clusters are likely to remain primarily confined to Lagos and Abuja.

Multistakeholder collaboration. Ecosystem enablers should invest in and seek out long-term partnerships with more agri-technology–focused innovations and hubs across Nigeria. Such efforts will provide DATs with more targeted and informed advice to optimize their business models and achieve scale. Specialized agri-technology co-working spaces and incubators (particularly in rural areas) could escalate partnerships among DATs and foster idea generation. With agriculture at the heart of the Nigerian government's diversification strategy, greater government backing of DAT support spaces is needed, as evidenced by the low score of 1 in multistakeholder collaboration.

The creation of an agri-technology ecosystem platform, similar to the World Bank's vision for the One Million Farmer Initiative in Kenya, could further

improve density. Such a platform would facilitate more collaboration between DATs and ecosystem players. Several DAT innovators expressed interest in this idea. They want a space where they can share ideas and promote offerings that bridge market gaps. The founder of a DAT social enterprise noted that ecosystem enablers such as the World Bank need to put more effort into aligning the market with producers. Additionally, such a platform could create a collective voice for DATs. This collective voice would strengthen their position and effectiveness when interacting with the government and other ecosystem enablers about what mechanisms could be introduced to unlock their growth potential.

Finance

Score: 1.5

Equity financing. Inadequate supplies of seed-level capital constrain the growth potential of DATs. The level of domestic market lending to the private sector has been very low, as reflected in Nigeria's low score on the indicator for equity funding for technology start-ups. According to the founder of a digital-profiling platform, the main source of capital for many entrepreneurs is personal funds or funds from friends and family. DATs require seed-level capital to develop their operations and test their ideas in the market. However, because agri-technology start-ups are deemed high risk, investors prefer to wait and see if such businesses can gain market traction before they invest. For example, one investor expressed a preference for investing in B or C funding rounds, that is, only once a business has established a foothold and attracted other investments. This creates an ineffectual situation in which DATs struggle to grow because of limited financial resources and investors wait to provide resources until DATs grow.

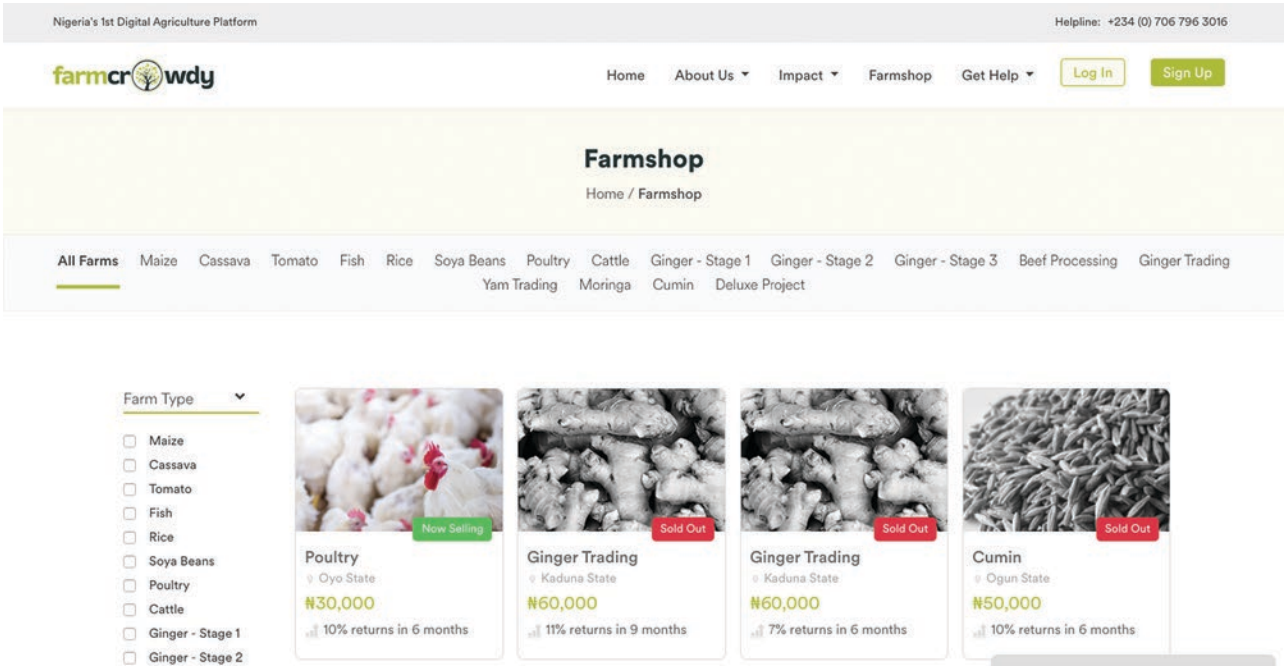
More angel and venture capital investors are needed to provide mentorship to DAT innovators to bridge the seed-funding gap (photo 3.2). By going beyond their traditional role, they can give credence to the view that venture and angel investors should embark on the growth journey with DATs and provide them with a host of supportive mechanisms to achieve key milestones together.

Domestic credit to private sector. Government and development partners can also help bridge the funding gap in Nigeria by dedicating more capital to DAT start-ups. Additional capital can be made available in two ways. First, partners can fund DAT start-ups directly by providing them with loans or matching funds. For example, the Central Bank of Nigeria has implemented a low-interest-rate loan program for start-ups that has proven to be "helpful for the ecosystem," according to an interviewed incubator. Second, they can invest through technology hubs that specialize in identifying viable businesses and that have a better view of high-potential models.

Financing for agricultural research and development. An evaluation of the agri-technology sector's financial landscape highlights funding shortages for agricultural R&D and agri-technology start-ups. In 2017, Nigeria contributed more funding (US$434 million) (Beintema and Stads 2017) to agricultural R&D than any other country in Sub-Saharan Africa. However, government spending on agricultural research as a share of total government expenditures was relatively low. Thus, there is a strong need for increased funding to be channeled toward agricultural research because more exploration in the space could lead to the discovery of ever more effective DAT innovations.

PHOTO 3.2

Farmcrowdy: Providing small-scale farmers access to finance, markets, and good agronomic practices in Nigeria



Source: © Farmcrowdy. Reproduced with permission from Farmcrowdy; further permission required for reuse.

Similarly, Nigeria exhibited the second-highest amount of financial investment (US$306 million) (Collon and Dème 2019) in technology start-ups in 2018. However, this level of investment is still considered inadequate given the size of the country's GDP. The issue of low investment is particularly pronounced in the agri-technology space.

Human capital

Score: 1.5

Extent of digital skills among population and graduate skill set. A review of the human capital landscape for DATs highlights severe gaps in digital literacy and basic ICT skills. Digital literacy is low across Nigeria, and agri-technology businesses find it difficult to recruit strong talent. For example, the chief executive officer of an agri-technology business accelerator and incubator said that he had had trouble finding people who had agriculture knowledge and technology skills. His company advertised twice for a job and was unable to hire applicants with the desired skill set. Nigerian universities exacerbate this situation by failing to adequately equip students with the skill sets demanded by the agri-technology market. Personnel from DATs and technology hubs interviewed highlighted the fundamental mismatch between what is taught and what is needed.[12] It seems that universities are currently using outdated curricula and are failing to adapt to changing market needs. After graduation, many students enroll in programs at training hubs to gain the requisite market skills.

Labor market for DATs. Nigerian universities are slowly investing in activities to develop the skills of their students. In response to the technology hub growth trend, Nigerian tertiary institutions have begun to establish their own incubators

and entrepreneurship programs. For instance, Covenant University established the Hebron Startup Lab in 2017, making it one of the first incubators in the country to be fully owned and operated by a university. The University of Nigeria has a similar program, Roar Nigeria Hub. Additionally, agriculture-focused universities, such as the Federal University of Agriculture and Michael Okpara University of Agriculture, are now introducing entrepreneurship programs.

Too few graduates possess basic technology and business skills. For example, the founder of an agri-technology firm in Nigeria expressed skepticism about an average university in the country being able to equip students with the skills the market requires. This skill gap forces DATs to leverage foreign talent, putting them at a cost disadvantage. Universities can address this constraint by redesigning agriculture-focused degree programs to align with the agri-technology space. Curriculum redesign would likely increase graduates' readiness to enter the agri-technology market (either as DAT innovators or as employees).

Future workforce. Field research (involving interviews and questionnaires with DATs and other private sector players) would help universities gain insight into what skills are needed in the market. This knowledge is critical given the low score resulting from an analysis of the development of the future workforce in Nigeria. These findings can influence the evolution and transformation of educational programs. Universities should then involve agri-technology players in validating their curricula. This collaboration with the private sector would increase universities' credibility and make their students more attractive to employers in the agri-technology sector.

Universities can ensure that graduates are equipped with the necessary skills to become DAT entrepreneurs by partnering with technology hubs and companies that provide training. Universities could host more hackathons to identify novel agri-technology ideas. They could also place students in incubation programs to further develop their skills and prepare them for entrance into the market. For example, Wennovation Hub (see box 3.1), an incubator that focuses on agriculture, trains university student unions and associations on how to run student hackathons to identify promising ideas. In addition, universities can schedule regular visits with renowned technology companies, such as Google and Andela, to provide ad hoc mentorship to students. Currently, Oracle (Lagos State Government 2018) and IBM (*Guardian* 2019) have implemented training programs throughout Nigeria aimed at closing the digital skills shortage. Universities can leverage such efforts.

Infrastructure

Score: 2

An assessment of the quality and availability of infrastructure in Nigeria indicates major gaps in four main areas: power, water systems, internet connectivity, and road networks. For example, a DAT entrepreneur in Nigeria noted that the road networks to farms are poor, and some roads to farm clusters need to be prioritized. Regular power outages still occur across the country, with only 45 percent of the population having access to power (36 percent in rural areas and 55 percent in urban areas) (USAID 2019b). Power outages have induced businesses to rely on private generators, which frequently carry high fuel and maintenance costs. According to the German Corporation for International Cooperation (GIZ), approximately 86 percent of Nigerian companies own or share a generator, from which 48 percent of their power is drawn (GIZ 2015).

Availability of transport. An additional major constraint affecting DATs concerns Nigeria's scarce and poor-quality road networks. The substandard road network in rural areas further exacerbates this restriction for DATs. Specifically, there are not enough road connections in farming communities, with the average distance from a farm to the nearest road being 14 kilometers (FAO 2018). DAT innovators, such as input providers, find it extremely difficult to deliver inputs to farmers, and market-link players struggle to transport harvested produce from farms to markets. Consequently, the disruptions caused to DAT operations limit their potential to deliver benefits to smallholder farmers. In response to the poor road networks, the government has increased investment in alternative modes of transport. For example, in 2018 the government commissioned the newly completed Abuja-Kaduna railway line (*Guardian* 2018b), and Lagos state is in the process of strengthening its water transportation system (Bello 2018).

Internet access. A lack of internet connectivity acts as a significant constraint for DAT start-ups. The low use of fourth-generation (4G) connectivity (4 percent of the population as of 2018; GSMA 2019b) is partly due to its limited availability in Nigeria, particularly in last-mile rural areas. As mobile providers invest in 4G, they have more incentives to launch it in high-traffic urban areas, which tend to yield greater profits. This specifically affects DATs because most of their agents work in the field, but they must also communicate with offices in urban areas. One DAT innovator described an incident in which a field agent was a week late meeting his work deadline because he had to travel to the closest town to use internet facilities. This delayed operations down the line. These instances are common for DATs operating in Nigeria. Nonetheless, Nigeria's assigned mobile internet spectrum (470 megahertz [MHz]) is far better than the average for Sub-Saharan Africa as a whole (268 MHz) (GSMA 2019b). This indicates that despite some challenges, the country is making headway in internet connectivity. However, the founder of a Nigerian social enterprise noted that broadband is expensive and of poor quality.

Reliability of water supply. The relatively low score assigned to the water availability dimension underscores Nigeria's unsustainable resource management practices. Human-caused contamination of the country's freshwater systems through oil spillage, effluents, and industrial waste exacerbates the country's declining water availability (Idu 2015). This issue is magnified in the agriculture sector, where less than 2 percent of cropland is irrigated (FAO 2018). Such minimal irrigation significantly limits overall farm yields.

Regulatory environment

Score: 2

An evaluation of Nigeria's regulatory environment highlights gaps in the existence and enforcement of intellectual property and contract protection policies, a lack of tailored regulations for DATs, and limited government transparency.

Ease of starting and doing business. Many DATs expressed concern that the regulatory environment is riddled with long, bureaucratic processes that slow and discourage DATs. For example, DATs that focus on collecting data via remote sensing are finding it difficult to obtain essential drone licenses from the Nigerian Civil Aviation Authority. The application process requires more than 16 different documents and subapplications and costs approximately 1.35 million Nigerian naira (US$3,750) to obtain. This is costly and time

consuming for DATs that typically lack such resources in the early stages of operation. Unfavorable import tariffs add to the challenge. Many DATs that provide advisory services import drones and other equipment necessary for operations, but high import fees strain their financial resources. Such fees are counterproductive to the scaling up of DAT innovation in Nigeria and indicate that regulatory updates are failing to keep up with advancements in the agri-technology sector.

Patent protection. The presence and enforcement of patent protection in Nigeria is nascent and does not play a catalytic role in the development of novel DAT innovations. Most DAT entrepreneurs interviewed noted an absence of adequate patent protection policies. This absence is highlighted by the founder of an agri-technology start-up, who commented that there were no adequate policies in place to protect innovations and that those available were not implemented properly. Under the Patents and Designs Act, the eligibility criteria by which inventions can be patented is very broad and vague, which exposes DAT innovations to unwarranted replication. During interviews, two DATs shared their experience of outside companies taking ownership of and implementing their ideas. In both cases, when the DATs alerted the authorities to the violations, there was no significant follow-up. This experience fosters a lack of trust between similar DATs, potentially weakening their desire to collaborate with one another.

Data protection policies. Although data policies scored low, in 2019 the Nigeria Data Protection Regulation was established to safeguard the privacy of personal data and to ensure that businesses and other stakeholders adhere to these practices (Nigeria 2019). This is particularly important for DATs because they generate a great deal of data on farmers via the services they provide. Given its recent formation in Nigeria, it is unclear whether this new policy is being promoted and enforced—stakeholder interviews showed that many DAT innovators are not aware of the presence of data protection policies in the country.[13]

Agricultural regulatory framework. Establishing an agri-technology-focused government committee would help improve the design of DAT policies and regulations. Given that agri-technology is a relatively new and rapidly evolving industry, an iterative process would help the government tailor its policies to match the needs of stakeholders in the ecosystem. One way to do this would be to let the sector operate without restrictions for a period, during which the government can observe the challenges facing DAT ecosystem players and draft policies based on their findings.

LESSONS LEARNED IN NIGERIA

- *Nigeria's DAT innovation ecosystem is largely private sector led,* with limited engagement from other ecosystem players or the government. Unlike Kenya, which benefits from engagement with development partners, Nigeria's private sector plays a stronger role in steering the development of the DAT ecosystem. Therefore, many DAT innovations have remained small in outreach to farmers, without significant support in farmer registrations or business model innovation. Private sector–led DAT innovation also means that solutions tend to focus on serving more-profitable farmers, which risks accentuating the digital divide.

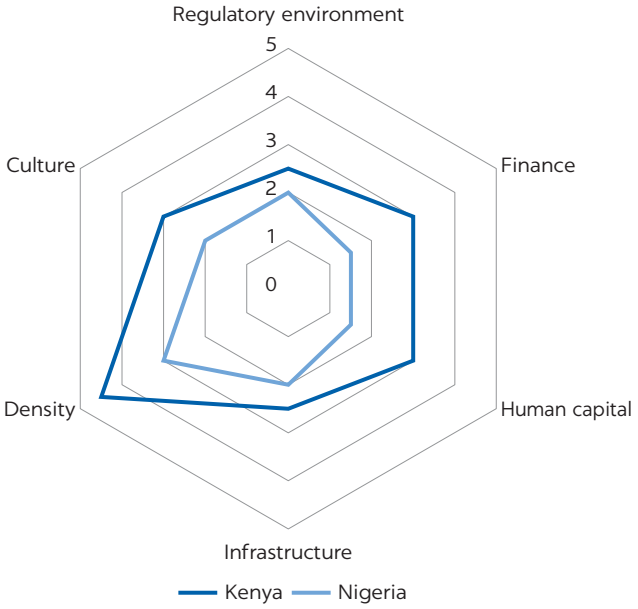
- *Nigeria benefits from having more agri-technology clusters beyond Lagos and Abuja,* which have the potential to promote inclusive agri-technology innovation. For instance, Wennovation Hub has established four incubators in Ibadan and Kaduna, with the objective of dispersing knowledge and a tech entrepreneurial culture beyond the main cities. Nigeria also has a more established, decentralized government compared with Kenya, which only instituted decentralized governance in 2013. Decentralized government entities can support the development of DAT clusters closer to farmers.
- *Despite having a larger economy and population, Nigeria's DAT innovation ecosystem still lags behind that of Kenya,* mainly because of challenges in the business- and agriculture sector–enabling environment. Nigeria also trails Kenya in human capital, infrastructure, and the regulatory environment. The country needs to increase investment in talent development, basic infrastructure development, and the cultivation of an enabling environment to attract more established DAT innovations, such as those operating in East Africa with up to a million smallholder farmer registrations.
- *Many smallholder farmers still lack the willingness and ability to pay for some services provided by DATs, particularly advisory services.* This demand constraint poses a challenge to DAT businesses that provide tailored data and advisory services to farmers for a fee. It effectively limits their ability to achieve scale because, most often, they must market to and recruit a community of farmers rather than focus on individual farmers. Pursuing farmer clients through farmer cooperatives and other farmer groups offers DATs a market entry opportunity. For example, a product manager at a DAT firm in Nigeria noted that it is expensive to reach individual farmers. However, using farm cooperatives and associations is associated with lower transaction costs and is less risky. Farmer membership fees paid to cooperatives could be used as pooled resources to acquire DAT products and services at affordable rates for a community of farmers. Other ecosystem actors, such as governments and development partners, could also provide access to DAT services where there is potential for positive externalities.
- *Government and development partners have a foundational role to play in supporting DAT innovations in Nigeria*. Governments can address these challenges by investing in fundamental necessities, such as basic infrastructure and human capital, as well as by promoting a business-enabling environment. Development partners can provide early-stage grant capital to innovators, support technology hubs, provide networking and mentorship opportunities, and invest in data-related public goods.

COMPARATIVE ANALYSIS

In aggregate terms, Kenya scored 3 out of 5 and Nigeria 2 out of 5 across the six ecosystem domains (figure 3.6). Both countries scored best on density, that is, the presence of networks that support productive relationships between different actors. Both countries scored relatively low on culture, which comprises the level of entrepreneurship promotion, research collaboration, economic freedom, and technology adoption. Despite the strategy to create an environment conducive to innovation, broader macro challenges need to be addressed for these countries to catch up with other global leaders in agri-technology innovation.

FIGURE 3.6

Kenya and Nigeria DAT innovation ecosystem assessment: Overview



Source: World Bank.
Note: DAT = disruptive agricultural technology.

Kenya's DAT ecosystem performs best on the ecosystem density dimension; on the other hand, Nigeria's DAT ecosystem ranks below Kenya's on all dimensions. Nigeria's above-average performance in density is driven by the high number of technology hubs (55) and DATs (35) in the country. However, Kenya performs even better in this area because of its greater number of DATs (58), its strong presence of technology hubs (30), and its high level of cluster development (Cornell University, INSEAD, and WIPO 2018). The Kenyan ecosystem is also known for hosting multiple networking events for start-ups, which enable closer collaboration and cross-pollination.

See the tables in appendix B for a summary of findings from the quantitative and qualitative analyses.

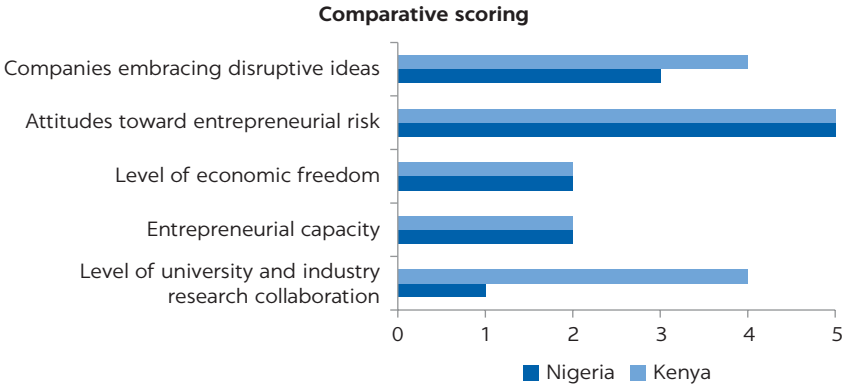
Entrepreneurial culture

Kenya and Nigeria score similarly on culture, with scores of 3 and 2 on a scale of 1 to 5 and similar scores across each indicator—except for "companies embracing disruptive ideas" and "level of university and research collaboration" (figure 3.7). The gap between Kenya and Nigeria regarding promotion of research collaboration is pronounced. Nigeria's below-average performance suggests a need for increased collaboration across stakeholders, such as academic institutions, government, and the private sector.

Both countries exhibit a below-average level of entrepreneurial capacity and activity, as well as of economic freedom. Although both countries have positive attitudes toward entrepreneurship, the promotion in schools of entrepreneurship as a viable career option has been limited. Furthermore, the government's support to the sector has been minimal. This assertion was echoed by stakeholders in both countries, who highlighted that viable innovators have shied away

FIGURE 3.7

Kenya and Nigeria DAT innovation ecosystem assessment: Entrepreneurial culture



Source: World Bank.
Note: DAT = disruptive agricultural technology.

from running their own businesses because there are no structures in place to support the scaling up of such businesses. Also, parents and schools are not encouraging young people to be innovators. This finding suggests that the government and other ecosystem actors need to provide a better enabling environment for entrepreneurs.

Density

Kenya and Nigeria both have high numbers of technology hubs and DATs (figure 3.8). However, when accounting for the size of the economy, the number of technology hubs in Nigeria still lags behind that of Kenya. Kenya and Nigeria collectively account for 53 percent of DATs present in Sub-Saharan Africa, with 58 and 34 DATs, respectively, according to the stocktaking analysis.

The high numbers of DATs in both countries may be connected to the size of their broader agriculture sectors (roughly 25 percent of GDP in each country) and the availability of incubators or hubs that promote innovation. However, these numbers pale in comparison to Israel, which has a population of less than 9 million people but has arguably the largest number of start-ups per capita in the world. Indeed, the ratio is 1 start-up for every 1,400 people, amounting to approximately 1,100 to 1,380 start-ups being established annually.

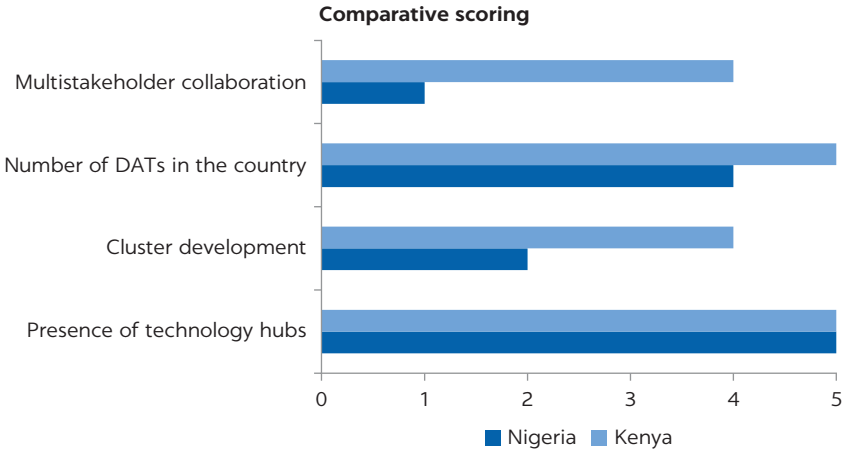
Kenya has one of the most well-developed and sophisticated business clusters in Africa, with more than 400 tech start-ups concentrated around Nairobi (Rafay 2016). Nigeria's clusters, however, tend to be less concentrated. Specifically, although Lagos and Abuja enjoy relatively well-developed start-up clusters, other areas of DAT concentration—such as Enugu, Ibadan, and Kaduna—are less developed. Overall, despite the high density scores in both countries, a significant push is needed to develop other clusters—beyond Abuja, Lagos, and Nairobi—that would be closer to farmers.

Finance

Both countries have recorded high flows of start-up funding compared with other Sub-Saharan African countries, but DATs only receive a fraction of this

FIGURE 3.8

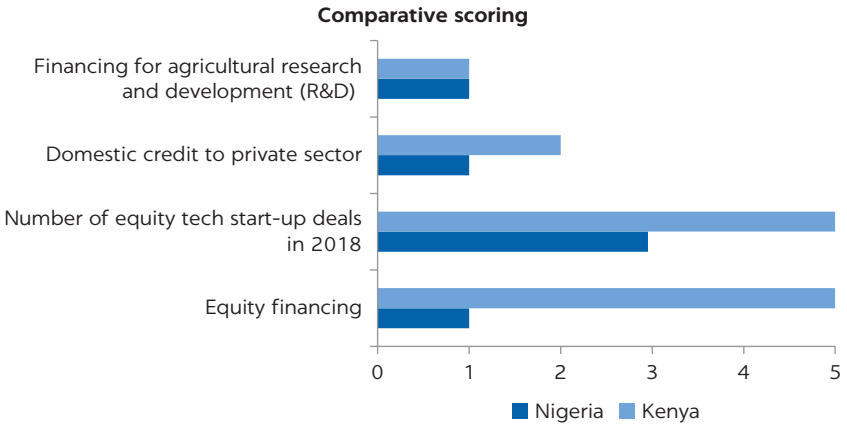
Kenya and Nigeria DAT innovation ecosystem assessment: Density



Source: World Bank.
Note: DAT = disruptive agricultural technology.

FIGURE 3.9

Kenya and Nigeria DAT innovation ecosystem assessment: Finance



Source: World Bank.
Note: DAT = disruptive agricultural technology.

funding (figure 3.9). Kenya and Nigeria were the top two destinations for start-up funding in Africa in 2018, raising US$348 million and US$306 million, respectively (Collon and Dème 2019). However, given that Nigeria's GDP and population are approximately four times that of Kenya's, Nigeria scored significantly lower than Kenya on this indicator, and its funding inflows are likely below potential. The share of overall funding that DATs received may be as low as 2 percent, given that most funding tends to go to financial technology, cleantech, and e-commerce (Kazeem 2019). These two countries are well behind global leaders in start-up investments. The United States ranked highest for start-up funding in 2018, at about US$160 billion—followed by China at US$110 billion, India at US$40 billion, and the United Kingdom at about US$25 billion (YoStartups 2019).

Kenya and Nigeria score poorly on "domestic credit to private sector," as well as on spending for agricultural research. Specifically, "domestic credit to

private sector" measures the financial resources provided to the private sector by financial corporations. Such support can be in the form of loans, purchases of nonequity securities, and trade credits and other accounts receivable that establish a claim for repayment. Furthermore, the amount spent by the government on agricultural research as a share of total government spending in Kenya and Nigeria—0.8 percent and 0.3 percent, respectively—is significantly lower than that spent by Mauritius (the top-spending country regionally), which spent 5.8 percent (Beintema and Stads 2017). This gap suggests an opportunity to invest more in primary research that could translate into technology innovations.

Kenya received more agri-technology funding deals than Nigeria, indicating that Kenya's DAT innovation ecosystem might be more developed. This deeper development could be due to the active participation of ecosystem enablers in Kenya, such as AGRA, Mercy Corps's AgriFin Accelerate, the MasterCard Foundation, Financial Sector Deepening Kenya, and others.

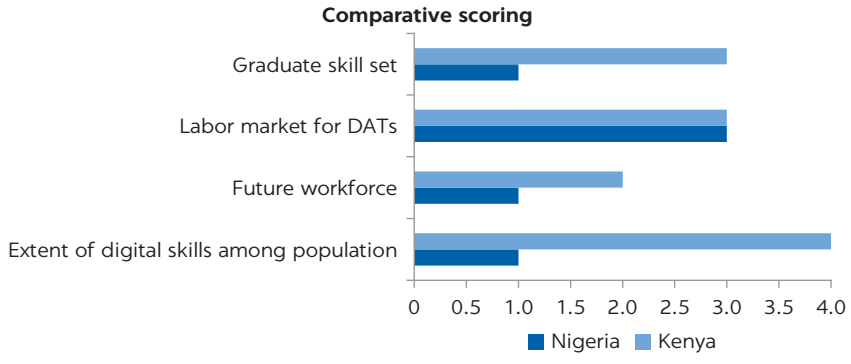
Human capital

Kenya scores higher than Nigeria on digital skills and graduate skill sets, potentially reflecting better skills development programs and university education (figure 3.10). As defined by the Global Competitiveness Index 2018, digital skills include computer skills, basic coding, and digital reading (World Economic Forum 2018). Nigeria promotes digital skills through training institutions such as Andela and support from multinationals like IBM (*Guardian* 2019). However, more needs to be done to develop the talent pool. Nigerian universities may need to revamp their curricula to be better aligned with the skills required by DAT employers. By comparison, the United States, which leads as the most start-up–friendly country in the world, is perhaps unmatched with regard to digital skills and graduate skill sets and is strengthened by the broader knowledge economy. Indeed, the United States is home to 119 institutions among the top 500 universities in the world for 2019, with many ranked among the top 10 (*CEOWorld* 2019).

Both countries could benefit from investment in their future workforces. Kenya and Nigeria each rank below average in terms of "future workforce" and

FIGURE 3.10

Kenya and Nigeria DAT innovation ecosystem assessment: Human capital



Source: World Bank.
Note: DAT = disruptive agricultural technology.

just above average in providing a "labor market." "Future workforce" encompasses school, life expectancy, critical thinking in teaching, and pupil-teacher ratio in primary education, as measured by the Global Competitiveness Index 2018. The indicator for "labor markets" comprises measures such as hiring and firing practices, ease of visa processing (for entrepreneurs or staff), and wage flexibility. Nigeria and Kenya have made strides in this area, including "visa on-arrival" systems (*Guardian* 2018a), but more policy reforms are needed to improve the labor climate.

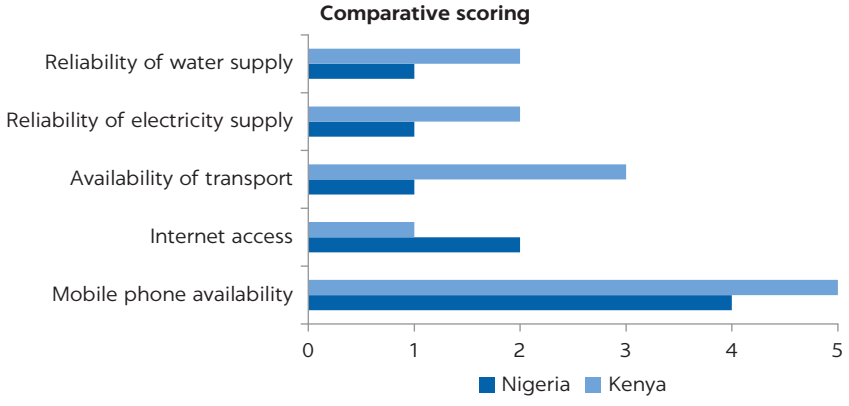
Infrastructure

Kenya and Nigeria exhibit different strengths related to infrastructure (figure 3.11). Kenya ranks higher in water and transport availability, as well as in mobile and smartphone penetration. Nigeria performs better in the number of internet users. An exemplary country that both Kenya and Nigeria can look up to with regard to infrastructure is Sweden. Sweden has a mature telecommunications, mobile, and broadband sector with well-developed Long-Term Evolution (LTE) infrastructure and high penetration of fiber broadband services, moving beyond 3G and 4G availability. These advances enable businesses in Sweden to develop data analytics and the internet-of-things innovations (Huawei 2018).

Kenya and Nigeria record high rates of mobile phone penetration in the Sub-Saharan African context, at 59 percent and 44 percent, respectively (GSMA 2019a). However, these numbers do not reflect a broader culture that embraces the use of technology—which would be beneficial to DATs—given that both countries rank in the bottom 20th percentile of ICT adoption according to the World Economic Forum's Global Competitiveness Index 2018. Despite high mobile penetration, Kenya and Nigeria score relatively low on ICT use compared with other countries globally. DATs operating in these countries have adapted their products so that they are accessible by basic feature phones, but still face difficulty in reaching customers living in remote areas. As ICT use continues to rise, DATs can improve their solutions by providing more complex, user-centric smartphone applications.

FIGURE 3.11

Kenya and Nigeria DAT innovation ecosystem assessment: Infrastructure



Source: World Bank.
Note: DAT = disruptive agricultural technology.

Regulatory environment

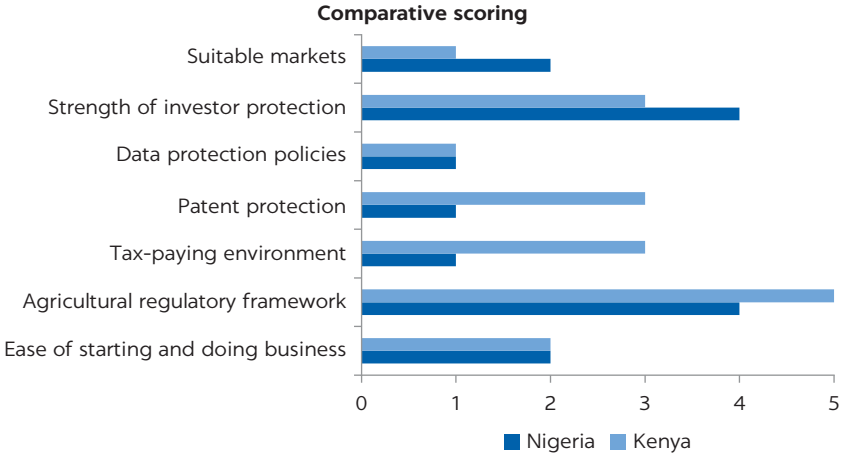
Kenya and Nigeria are below global averages regarding the "ease of starting a business," as well as in creating and enforcing policies for data protection (figure 3.12). Of 190 countries surveyed, Kenya and Nigeria rank 126th and 120th, respectively, on the "ease of starting a business" (World Bank 2019a). This low ranking results from the difficulty and high cost of registering new limited liability companies. DAT start-ups are obliged to spend significant time and resources to formally register their businesses. Furthermore, both countries currently lack specific laws governing data protection (CNIL, n.d.). As such, DATs that provide or depend on data collection to generate value can encounter customer or partner distrust because of the lack of a legal framework for data protection.

Both countries could learn from Israel, a leading agri-technology ecosystem and a pioneer in creating enabling legislation for both foreign and local companies (box 3.2). For example, the Israeli government accelerated the venture capital movement in 1993 by creating a program called Yozma that offered tax incentives to foreign venture capital firms. Today, Israel continues to be a leader in enabling and encouraging the emergence of start-ups through investment in research, development, and innovation through the Israel Innovation Authority (StartupBlink, n.d.). Kenya and Nigeria currently lack specific laws governing data protection, which can lead to customer or partner distrust for DATs that provide or depend on data collection to generate value.

Both Kenya and Nigeria have enacted appropriate regulations to prevent discrimination against specific groups in agricultural investment and activity. Globally, each maintains high numbers of nondiscriminatory measures that enable domestic, foreign, and small-scale businesses to participate. Kenya has 24 such measures and compares favorably to Spain, the global leader with 28 measures, whereas Nigeria is somewhat behind Kenya with 17. Nigeria performs slightly better than Kenya in investor protection, while the reverse is true in the area of creating and enforcing policies for patent protection.

FIGURE 3.12

Kenya and Nigeria DAT innovation ecosystem assessment: Regulatory environment



Source: World Bank.
Note: DAT = disruptive agricultural technology.

BOX 3.2

Lessons from Israel and New Zealand

New Zealand and Israel have successfully invested in developing disruptive agricultural technologies. New Zealand is a global leader in the agri-technology space, as well as the top performing country in the "starting a business" category of the Doing Business Index (World Bank 2019a). In New Zealand, each individual founder enjoys relationships with an average of 15 other founders (Startup Genome 2018). In Israel, the government provides support for research and development (R&D), commercial-oriented research, increasing social tolerance for failure, and the fostering of other aspects of a supportive ecosystem. Israel maintains a thriving agri-technology sector and is known for integrating ingenuity with cutting-edge agricultural techniques. Various features of Israel's ecosystem can be instructive for Africa.

In the financial sector, Israel's Innovation Authority offers R&D support for promising agri-technology companies, granting 20 to 50 percent of approved R&D budgets to aid in the development of new products and technologies (Israel 2019). The Innovation Authority has played a huge role in enabling funding for agri-technology solutions. Furthermore, universities and the private sector collaborate on research. A model that links government funding with private sector involvement has served to commercialize resulting innovations and cycle profits back into further research. Such a vibrant ecosystem sustains a greater number of researchers.

Israel also promotes a risk-taking culture that values experimentation, does not stigmatize failure, and allows entrepreneurs to bounce back after missteps. Such support is illustrated in smart bankruptcy policies that are less onerous than in many other Organisation for Economic Co-operation and Development countries (Deloitte 2018).

NOTES

1. For more information on the Big Four Agenda, see https://big4.president.go.ke/.
2. For more information on Kenya Vision 2030, see https://vision2030.go.ke/.
3. Only 20 percent of Kenya's land is suitable for farming (USAID 2019a).
4. The aggregate score is based on a simple average of the individual scores for each of the six assessment areas, which were ranked on a scale of 1 to 5, with 5 being the best possible score and 1 being the worst possible score. A score of 3 represents a midpoint or average score. The assessment area scores were derived from the performance of the case study countries across different indicators. The countries were benchmarked against the top-performing country globally or regionally, depending on the specific indicator.
5. For more information on Innovation Week, see https://innovationweek.co.ke/.
6. For more information on Sankalp Forum, see http://www.sankalpforum.com/.
7. For more information LAPPSET, see http://www.lapsset.go.ke/.
8. DigiFarm is a technology platform tailored to smallholder farmers, providing them with financing and information about inputs and various crops and animals. DigiFarm is currently run by a partnership of Safaricom, iProcure, and FarmDrive.
9. For more information on the contribution of agriculture to Nigeria's GDP see theWorld Bank Indicators database, at https://data.worldbank.org/indicator/nv.agr.totl.zs.
10. For more information on employment in agriculture in Nigeria, see theWorld Bank Indicators database, at https://data.worldbank.org/indicator/sl.agr.empl.zs.
11. For more information on the Dalberg stakeholder interviews, May 2019, see appendix B.
12. Dalberg stakeholder interviews, May 2019.
13. Dalberg stakeholder interviews, May 2019.

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4 Conclusions, Recommendations, and Future Areas of Research

Case studies of the innovation ecosystems in Kenya and Nigeria, together with the regional stocktaking exercise, show how continuous investment in the digital ecosystem can help disruptive agricultural technologies (DATs) scale up and strengthen their impact. DAT ecosystems appear to be at an inflection point, at which several trends are emerging:

- A profusion of small companies are starting to bundle their services together to achieve a wider scale and deeper and stronger financial viability.
- Emerging DATs can operate successfully off-line at the farm level, updating only when connected in urban areas.
- Farmer databases support DAT development and uptake; these databases are a major investment cost for start-ups.
- Well-developed mobile payment systems are an essential ingredient for most DAT enterprises to function effectively.
- Financial technology solutions are bridging liquidity gaps for farmers to the benefit of the entire supply chain, from input suppliers to off-takers. Examples include installment payment systems, very short-term loans, and insurance products.
- The biggest challenge is not the existence of solutions but rather the sustaining of these solutions and the framework within which they would operate. Leading ministries of agriculture are seeking to systematically invest in knowledge, innovation, and the incubation ecosystem for digital technologies and female and youth entrepreneurship.

Government officials, entrepreneurs, and other food system actors agree that a digital transformation strategy is needed for Africa's food system. Such a strategy would help realize the enormous potential of digital technologies to improve productivity and resilience, promote inclusive job creation, and reduce poverty in African countries. With concerted effort, every African farmer, agribusiness, and ministry of agriculture can be digitally enabled. Table 4.1 lays out a set of Digital Agriculture Moonshot targets for Africa to achieve this vision.

How can African countries best achieve these ambitious targets? Table 4.2 summarizes potential entry points for public and private sector actions to facilitate broader adoption of DATs and harness their impacts to improve food

TABLE 4.1 Digital Agriculture Moonshot targets for Africa

EVERY AFRICAN FARMER, AGRIBUSINESS, AND MINISTRY OF AGRICULTURE IS DIGITALLY ENABLED BY 2030				
RURAL DIGITAL INFRASTRUCTURE	**AGRICULTURE DIGITAL SKILLS AND LITERACY**	**AGRICULTURE DIGITAL PLATFORMS**	**DIGITAL AGRI-FINANCE SERVICES**	**DIGITAL AGRI-ENTREPRENEURSHIP**
Universal internet coverage* (* data for rural areas)	All 15-year-old students with basic digital skills and competencies* (* data for rural areas)	All individuals can prove their identity digitally* (* 100% of governments with digital farmer IDs)	Universal access to digital financial services* (* data on agriculture finance services)	Tripling the number of new digitally enabled businesses created annually* (* doubling the number of new digitally enabled agribusinesses and agri-technology firms created annually)
Affordable internet for all at less than 2% of GNI per capita* (* data on access by farmers at less than X% of agricultural GDP/farmer)	100,000 graduates in advanced digital skills programs annually* (* of which 20,000 graduated as agronomists with digital skills in the curriculum)	Doubling of online services index rating for all governments* (* data on rural areas)	Africa-wide payments infrastructure and platform in place* (* 80% of farm subsidies provided through digital forms)	Financing for venture capital to reach 0.25% of GDP* (* financing for agri-technology entrepreneurship to reach X% of agriculture GDP)
Doubling broadband connectivity by 2021* (* data on rural areas)	Percentage of rural schools with digital education modules	At least 50% of the population regularly uses the internet to access government or commercial services* (* 50% of farmers access weather and price information regularly through digital platforms)	M-Pesa–equivalent platform for farmers for undertaking all financial transactions digitally	Percentage of value added of food traded through digital tools
Percentage of water used in irrigation systems being measured through digital technologies	Digital literacy: Percentage of farmers using digital hardware (for example, sensors and drones) and software to collect, assemble, process, and analyze data (with gender disaggregation)	Regional crowdfunding and peer-to-peer platforms for agriculture inputs, outputs, and financing	Percentage of farmers that access insurance through digital solutions	Percentage of volume of food traded with digital traceability information available
Percentage of agriculture land and soil information available in open data sources	Mobile literacy: 100% of farmers have mobile literacy (including mobile apps that illiterate farmers can use)	Significant part of agriculture extension (public and private) delivered through digital content and devices* (* that is, soil scanners [Soil Cares], pico projectors [Digital Green] and microcomputers and tablets)		

Source: World Bank.
Note: * indicate disaggregated targets for agriculture. Text in blue indicates targets applicable only to agriculture.

TABLE 4.2 Potential entry points and actions to facilitate broader adoption of digital technologies

RECOMMENDATIONS	SHORT TERM	MEDIUM TERM
POLICY AND REGULATORY REFORMS		
Develop an e-agriculture strategy to be integrated into the overall agriculture sector development strategy.	x	
Develop data policies that clarify data privacy, ownership, and sharing rules, as well as those mandating data collection and protections.		x
Enable telecommunications infrastructure and payment systems in rural and remote areas to ensure good quality and predictable rural connectivity.		x
INSTITUTIONAL REFORMS		
Adopt pluralistic extension and service-delivery approaches to enable digital innovations and solutions to be tested and tried for smallholders. Digital innovators can link input suppliers and service providers on a digital platform.	x	
Develop incubators in higher-education institutions and develop good-quality curricula for digital skills, innovation, and applications.	x	
Link innovators with local and international investors and farmers through periodic forums, conferences, and industry network groups.	x	
PUBLIC INFRASTRUCTURE INVESTMENTS		
Public infrastructure investment can be made in the areas of collecting foundational data and developing platforms such as the following: - Digital farmer registrations - National soil maps - Real-time agricultural weather observatory and early warning systems (satellite, geospatial) - E-government systems for all public services and resources administered through ministries of agriculture - Digital surveillance technologies for pests and diseases	x	
Support rural broadband access and last-mile internet delivery programs.		x
Invest in agricultural research, including partnerships between academic programs and industry tailored for digital agriculture technologies and innovations	x	
Develop rural road networks, power, and irrigation infrastructure.	x	
PRIVATE SECTOR INITIATIVES		
Establish associations as a platform for dialogue with governments.	x	
Establish incubator hubs to nurture agri-technology start-ups and use these to identify investment opportunities.	x	
Host events for disruptive agricultural technology innovators to discuss past failures and successes.	x	

Source: World Bank.

system outcomes. Policy opportunities to promote digital innovation include policies to stimulate competition, effective intellectual property protections, incentives for technology diffusion, innovation in public service provision related to e-vouchers or e-extension, investments related to digital skills, open science initiatives, research infrastructure, and ongoing dialogue with the private sector to adapt to evolving needs. Public investments to promote DAT development are most effective when they follow the cascade approach to ensure that they crowd in, rather than crowd out, private investments. The private sector also has a role to play in communicating its needs to public actors and in fostering private-private dialogue to speed up learning and improve decision-making.

Governments can support DATs as follows:

- Invest in a policy for pluralistic extension and service delivery approaches to enable digital innovations and solutions to be tested and tried for smallholders. Most of these solutions require partnerships between input suppliers, service providers, and digital innovators. Many existing agricultural policies have scope for trying alternative and pluralistic approaches. It is difficult to develop these solutions in the absence of an enabling policy environment.
- Invest in a policy and platforms for data collection and access from public and private sources to enable the development of appropriate products and services for smallholders. Data policy and platforms will also lead to the development of a foundation for data- and evidence-based policy making. Digitizing farmer data would enable the development of data-based and digitally enabled products and services. Access to good-quality data will aid in the development of innovative service delivery and products.
- Invest in e-governance systems for all public services and resources being administered through ministries of agriculture. Channeling input subsidies and other incentives through digital services is also critical for the development of products and services.
- Invest in enabling policies for telecommunications infrastructure and payment systems in rural and remote areas to enable good-quality and predictable rural connectivity. Connectivity for smallholder farmers and service providers would enable better access to services and digital solutions.
- Invest in an agricultural technology start-up policy to enable innovators in the digital space to operate and grow. Also, invest in the enabling ecosystem for agricultural technology innovations to facilitate investment by country-level, regional, and international innovators.

At the farm level, to promote efficiency and sustainable production, land and soil information could be made readily available in public databases. Irrigation systems could be monitored digitally to optimize water use. Farmers themselves will require a higher level of digital skills, which will entail revamping both graduate and basic education programs to incorporate digital and mobile literacy. Agricultural extension can be delivered through digital content and devices, and other digital platforms could connect farmers to weather and price information, input suppliers, off-takers, and finance. Finally, the number of new digitally enabled agribusinesses could be doubled by 2030. Financing for agri-technology entrepreneurship could reach 0.25 percent of agriculture GDP, and the volume of food traded through digital platforms, including those that enhance traceability, could be increased.

An important lesson drawn from interviews with African DAT innovators is that disruptive technology investments are most effective when they are made in tandem with efforts to improve basic agricultural infrastructure and services. For example, satellite-based data-collection approaches, while powerful, rely on ground-truthing from traditional agricultural surveys. Digital price-discovery apps are valuable to poor and isolated farmers only when farmers can physically move their product to realize the higher price, which requires adequate road and transport infrastructure.

Expanding access to irrigation—currently at less than 5 percent in Africa—is a precursor to benefiting from internet-of-things soil moisture sensors. In this sense, digital technologies are complementary to more traditional agricultural investments.

A major challenge for the agriculture sector is that the average age of farmers in Africa is greater than 50 (Arslan 2019), but the adoption of digital solutions tends to be higher among youth. Achieving digital skills will require targeted training for farmers and extension agents. Ministries of agriculture and other government actors can further their efforts to promote digital infrastructure, including digital farm registries and digital marketing platforms, as appropriate. They can also work to digitize their own systems, including statistical systems. To promote digital agri-entrepreneurship, some African countries are using matching grant and acceleration funds to help firms through the challenging scale-up phase.

A key consideration for digital agriculture initiatives is the challenge of inclusion. Digital agriculture holds promise for youth inclusion and employment, as well as risks for gender equality. Further research is needed to understand the source of digital agriculture gender gaps and specific strategies to address those gaps. At a minimum, digital literacy for women and digital entrepreneurship support for women should be emphasized to promote gender inclusion.

Although the most effective digital technology approaches will differ across countries and communities, what remains clear is that there is vast potential for these technologies. The Innovation, Knowledge, and Challenge Conference showcased the One Million Farmer Initiative, a model for a sustainable innovation ecosystem in which DATs are connected to farmers through an end-to-end platform (box 4.1). Scaling this model and other proven innovations can help Africa achieve its objectives related to economic growth, poverty reduction, food security, and employment in the agriculture sector.

This book sheds light on the scalable start-ups active in the DAT space. The book contains information and insights about certain characteristics of these firms, as well as attributes of the major innovation ecosystems in which they are operating. However, much less is known about the adoption and impact of these technologies at the farm level. Anecdotal evidence suggests the impact could be large, but most firms are at such an early stage that it is premature to say for certain. Ultimately, the argument for investing in DATs hinges on the experiences of farmers themselves in using these technologies. Governments, the World Bank, and other development partners are starting to collect more systematic data on this topic, for example, through new questions on agricultural censuses and farm surveys. Outreach to farmers to better understand the constraints to DAT adoption, from their perspective, is a critical information gap. At the level of individual technologies, more research is needed to develop impact assessments and evaluation systems for existing DATs, to expand the evidence base for digital and disruptive agriculture approaches. At the country level, national innovation ecosystem diagnostics would enable countries to assess the key investments and policies required to support agriculture sector innovation. The field is ripe for future research to generate benefits to the agriculture sector and economic development in Sub-Saharan Africa.

BOX 4.1

One Million Farmer Initiative

The One Million Farmer Initiative aims to strengthen Kenya's digital agriculture ecosystem and provide a proof of concept for further disruptive agricultural technology (DAT) scaling up in Africa.

A vibrant innovation ecosystem is crucial to scaling up DATs. Countries can achieve such an ecosystem by systematically investing in knowledge, innovation, policies, capital, and incubation. These investments would enable innovators to engage in iterative processes to improve their technologies and business models, prove their impact and return on investment, and rapidly extend their reach. Kenya already has a budding innovation ecosystem, as evidenced by the sudden surge in DATs. This momentum now needs to be harnessed to drive the scaling up of DATs.

The World Bank—along with the Ministry of Agriculture, Livestock, Fisheries, and Irrigation and the Korea–World Bank Partnership Facility—has launched a pilot project in Kenya entitled the One Million Farmer Initiative. This initiative is a three-year partnership that will link 1 million Kenyan farmers across 14 different agricultural value chains and 45 counties in Kenya to a digitally enabled platform. The platform will integrate and coordinate the activities of leading Kenyan-focused DATs. The initiative will build on and link to existing World Bank programming in Kenya, most notably the National Agricultural and Rural Inclusive Growth Project and Kenya Climate Smart Agriculture Project.

Through partnership collaboration, the One Million Farmer Initiative will bring together a group of best-in-class DATs in Kenya selected through the challenge component of the Innovation, Knowledge, and Challenge Conference as part of the first cohort of innovators. The One Million Farmer Initiative will link these innovators to experts, investors, agribusinesses, and government partners at the national and county levels. All activities will be centered on a common mission of delivering value to the 1 million Kenyan smallholder farmers. A secondary objective is to create demonstration effects to validate the replication of this digitally enabled innovation ecosystem platform in countries beyond Kenya. Currently, the World Bank envisions extending the initiative to an additional three to five African countries drawing on lessons learned in Kenya.

The initiative with the first cohort of innovators will offer a holistic solution to focus on farmers' challenges. Through the One Million Farmer Initiative, the first cohort of innovators will achieve economies of scale in reaching smallholder farmers. The platform will enable this first cohort to take advantage of large-scale identification, data-collection, and data analytics services (for example, agronomy content and geospatial farm and soil maps), as well as digitized farmer profiles. As such, each ecosystem actor will save on undertaking these activities themselves, or on spending more resources by operating without this information. Consequently, this opportunity will translate into improved business model sustainability for the first cohort.

Smallholder farmers will also receive a host of benefits derived from the One Million Farmer Initiative. They will have access to affordable services that address major difficulties in their operations. By adopting the innovations available on the platform, they will be able to increase their yields, receive financial services, access local and international markets, and more. Ultimately, smallholder farmers will be able to increase their incomes and reduce poverty by optimizing their operations through innovations.

To mobilize innovators who will join the One Million Farmer Initiative platform as the first cohort of innovators, 23 leading DAT innovators were invited to present their strategies. The incentives included the chance to receive performance rewards, acceleration funding, incubation, mentoring, and financial support to scale up their innovations in Kenya. From the private and nonprofit sector, 14 innovators were selected by a jury as the first cohort of innovators to join the One Million Farmer Initiative. The following companies were the selected innovators in four categories—productivity, market links, financial inclusion, and data analytics.

Category 1: Productivity-based DATs

- **DigiCow,** a mobile-based service delivery platform is linking small livestock owners to veterinary and artificial insemination services and feed suppliers, aggregating demand as a business enterprise. The result is a significant increase in milk productivity.

continued

Box 4.1, *continued*

- **Digital Green** uses a video-enabled approach to reach large numbers of smallholder farmers with agricultural extension advisory services in a scalable and cost-effective way for crops and commodities, resulting in an increase in crop productivity.
- **Farmers Pride** combines a franchise model, technology, and village youth agents to bridge input, service, and information gaps among rural smallholder farmers.
- **Precision Agriculture for Development** reaches farmers with personalized agricultural advice through their mobile phones.
- **SunCulture** develops and offers solar-powered smart irrigation systems.

Category 2: Market links DATs

- **M-Shamba,** a digital extension platform, uses interactive voice response services to extend and transfer agricultural technologies to smallholder farmers.
- **TruTrade Africa** uses cloud-based mobile and online applications to provide smallholder farmers with links to markets and fair prices for their produce.
- **Tulaa** uses mobile technology and artificial intelligence to provide smallholder farmers with quality agricultural inputs on credit. It also brokers the sale of their crops at harvest time.

Category 3: Financial inclusion DATs

- **ACRE Africa** links farmers to crop, livestock, and index insurance products to shield them against unpredictable weather conditions.
- **Agri-Wallet** provides a mobile financial tool to connect farmers to agri-buyers, agro-vets, and service suppliers, as well as a special digital wallet that combines savings, input supplies, and market access and loans to accelerate cash transfers within the agriculture sector.
- **Arifu** is a personal learning tool that farmers can use to chat with on any mobile device to learn new skills and to access opportunities.

Category 4: Data analytics DATs

- **Astral Aerial** operates affordably priced drones that can cover 1,000 acres per flight, using sensors to detect crop health.
- **Oakar Services** is a geospatial consulting firm focused on providing a geographic information system, remote sensing, and other related geospatial consultancy services.
- **UjuziKilimo** is a real-time soil testing service using sensors and mobile phone technologies to provide precise and actionable agricultural information to farmers.

Future follow-up activities will include a design workshop with selected innovators and a workshop with government and innovators on data collection, analytics, and decision-making.

Applying the One Million Farmer Initiative Model to Other Countries

The World Bank plans to continue its engagement with the 14 DATs selected through the pilot initiative. As an immediate next step, a workshop was organized with all 14 DATs in Nairobi on December 9, 2019. The main objectives of the workshop for the DATs were as follows:

- Define milestones to be achieved to receive a performance-based grant (share of the US$1 million total grant amount across all awardees in this cohort)
- Receive nonfinancial assistance in the form of incubation and mentorship support as well as connection to investors, agribusinesses, and technical experts
- Strategize to obtain access to the 1 million farmers and work directly within the World Bank's One Million Farmer Initiative Project, as well as work closely with the Kenyan government

Once proof of concept is established, this initiative could be scaled up in several other countries, including Côte d'Ivoire, Rwanda, Senegal, and Uganda.

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APPENDIX A

Detailed Stocktaking Methodology

INCLUSION AND EXCLUSION CRITERIA FOR THE DATABASE AND CLASSIFICATION OF THE AGRICULTURAL CHALLENGES

TABLE A.1 Inclusion and exclusion criteria

Overall inclusion criteria • Current operations in Sub-Saharan Africa, irrespective of the geography of business establishment • Applicable for crops, livestock, and horticulture • Solutions are centered on farmer as an ultimate consumer	
Overall exclusion criteria • Solutions focused on retail, household, hobbyists, and the like • Solutions in North Africa, with no presence in Sub-Saharan Africa • Traditional agro-processing and milling companies	
Agricultural productivity	Inclusion criteria • Video tools and short message service (text messages) with agronomic information, climate-smart advisory, weather information, extension services • Chatbot services, peer-to-peer learning platforms • Pest and disease management tools, medical assistance tools for livestock, tools to protect livestock from predators • Digital services increasing access to inputs and mechanization • Solutions increasing access to bio-fertilizers, bio-pesticides, or bio-products for agriculture • Aquaponics, hydroponics with farmer as the consumer Exclusion criteria • Seed and fertilizer manufacturing and distribution companies with no disruption
Market links	Inclusion criteria • Services linking farmers with buyers (intermediaries, households, industry, or government) • Solutions providing livestock trading to farmers • Supply chain logistics and traceability Exclusion criteria • Farm cooperatives • Pure logistics companies

continued

TABLE A.1, *continued*

Financial inclusion	Inclusion criteria • Digital services increasing access to credit (which may lead to increase in access to inputs and mechanization) • Services and solutions increasing access to crop insurance, generating credit scoring and creditworthiness of farmers • Online crowdfunding platforms for farms Exclusion criteria • Insurance products not geared toward agriculture
Data analytics and intelligence	Inclusion criteria • Livestock identification, livestock or cattle management software, fish management software • Data infrastructure, remote-sensing and mapping technologies, drone, satellite, or aerial imagery • Precision-agriculture tools such as internet-of-things devices, soil sensors, farm-management software, cloud-based management information systems • Greenhouses (controlled-environment agriculture [CEA] construction), soil testing • Digital farmer profiles only
Alternative energy	Inclusion criteria • Solar, wind, or renewable energy for irrigation, cold storage, mechanization, or greenhouses • Bio-gas and bio-diesel for farm inputs

Source: World Bank.

IMPACT ASSESSMENTS OF DIGITAL TECHNOLOGY

TABLE A.2 USAID digital agriculture framework

MAIN FINDING	LOCATION; PRODUCT; TECHNOLOGY; STUDY
Improve market transparency	
Greater arbitrage opportunities, reduction in spatial price dispersion, lower wastage, increase in both consumer and producer welfare	• Kerala, India; fisheries; mobile phone coverage; Jensen (2007) • Uganda; range of crops; radio; Svensson and Yanagizawa (2008) • Niger; grain; mobile phone coverage: aker (2010)
Increases in farm-gate prices from improvements in bargaining power with middlemen, greater market participation in remote areas through more efficient coordination	• Uganda; maize and bananas; mobile phone coverage; Muto and Yamano (2009) • Madhya Pradesh, India; soybeans; internet kiosks; Goyal (2010) • Gujarat, India; range of crops; SMS; Mitchell (2014)

continued

TABLE A.2, *continued*

MAIN FINDING	LOCATION; PRODUCT; TECHNOLOGY; STUDY
Context-specific factors and various marketing and institutional constraints can blunt benefits	• Rwanda; range of crops; mobile phone adoption; Futch and Mcintosh (2009) • India; range of crops; SMS; Fafchamps and Minten (2012) • West Bengal, India; potatoes; SMS; Mitra et al. (2015) • Ethiopia; cereals; mobile phone coverage; Tadesse and Bahiigwa (2015)
Enhance farm productivity	
Facilitates adoption of improved inputs by providing extension advice and weather forecasts at a lower cost and encouraging agricultural investment decisions	• Ethiopia; range of crops; video; Gandhi et al. (2009) • Gujarat, India; cotton; hotline voice service; Cole and Fernando (2012) • Ghana; range of crops; mobile phone coverage; Al-Hassan, Egyir, and Abakah (2013)
Improvements in rural households' food security, income, value of assets through enhanced management practices	• Philippines; range of crops: mobile phone adoption; Labonne and Chase (2009) • Sri Lanka; fruit and vegetables; SMS; Lokanathan and de Silva (2010) • Peru; range of crops; mobile phone coverage; Beuermann, McKelvey, and Vakis (2012)
Success of digital technology interventions depends on broader institutional support, such as political empowerment, human capital, and income inequality.	• Cross country data; range of crops; ICT; Lio and Liu (2006) • Morocco; range of crops; mobile phone adoption; Ilahiane and Sherry (2012) • Kenya; SMS; Ogutu, Okello, and Otieno (2014)
Enable efficient logistics	
Optimize supply chain management, enhance coordination of transportation, delivery of products, and improving capacity utilization	• South Africa; web-based systems; van Rensburg (2004) • Zambia; SMS-based service; Dixie and Jayaraman (2011)
Ensures food safety in global agriculture product chains, tracing from point of origin to consumers	• Namibia; beef; radio frequency identification; Cabrera et al. (2010) • Colombia; coffee; Karippacheril, Rios, and Srivastava (2011) • Mali; mangoes, mobile phone platforms; Annerose (2010)
Facilitates secure payments, allows fast and safe transfer of funds to pay for products and inputs, agricultural subsidies, or remittances	• Nigeria; e-wallet; Grossman and Tarazi (2014) • Kenya; mobile money; Jack and Suri (2014); Mbiti and Weil (2015)

Source: Deichmann, Goyal, and Mishra 2016.
Note: ICT= information communication technology; SMS = short message service; USAID = US Agency for International Development.

LIST OF SOURCES CONSIDERED FOR THE DATABASE

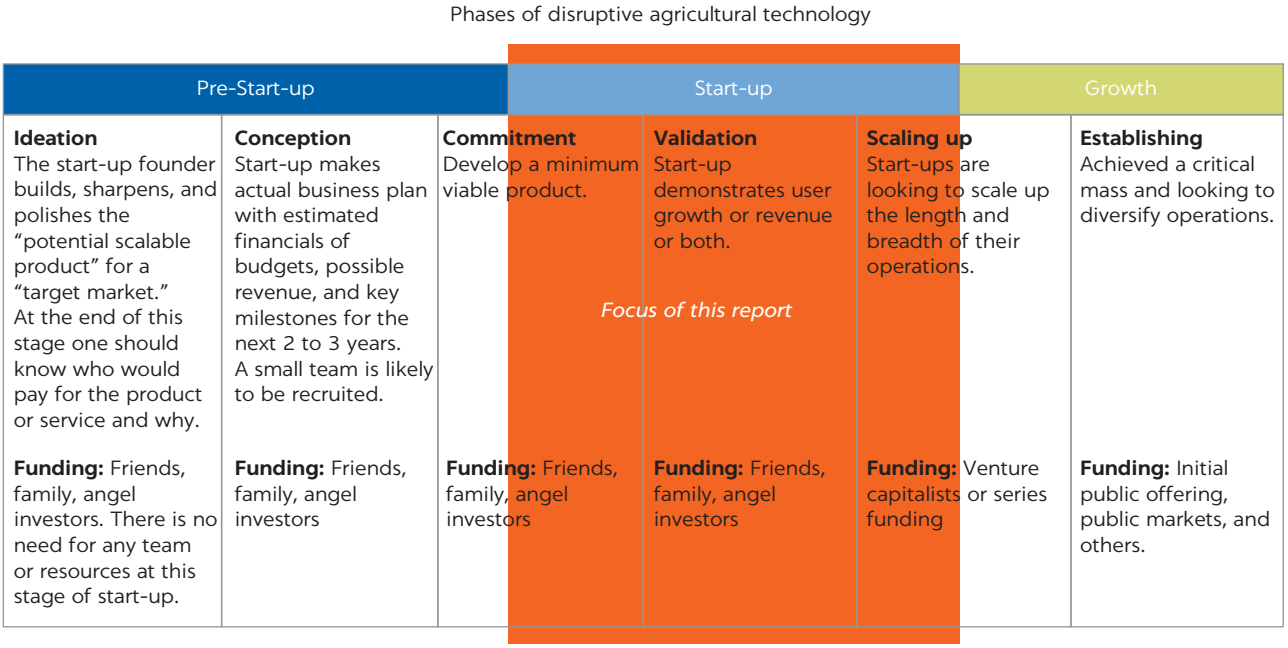
TABLE A.3 Sources considered for the database

	DATABASE	DESCRIPTION	USED FOR STOCKTAKING?	WEBSITE
1	PitchBook	60 companies listed	Yes	https://pitchbook.com/
2	Crunchbase	Crowdsourced with no quality control; 217 companies listed	Yes	https://www.crunchbase.com/
3	F6S	Crowdsourced with no quality control	No	https://www.f6s.com
4	Tracxn	Artificial intelligence–based data collection with quality control; 200 companies listed	Yes	https://tracxn.com/
5	AsokoInsight	About 200 companies listed; focused on agribusiness rather than agri-technology	No	https://asokoinsight.com/search/companies
6	VC4A	Crowdsourced, founders can put up information themselves; 452 companies listed although it is not verified	No	https://vc4a.com/ventures/sector/agribusiness/
8	Google searches	One-by-one searches	Yes	

Source: World Bank.

FIGURE A.1

Phases of disruptive agriculture: Focus on validation phase with minimum viable product



Source: World Bank.

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APPENDIX B

Detailed Case Study Methodology

TABLE B.1 Indicators and scores for Kenya and Nigeria

ASSESSMENT AREA	INDICATOR	DATA RANK OR SCORE	RAW DATA				DALBERG-ANALYZED SCORE		AGGREGATE SCORE	
			KENYA	NIGERIA	TOP COUNTRY	BOTTOM COUNTRY	KENYA	NIGERIA	KENYA	NIGERIA
Entrepreneurial culture	Attitudes toward entrepreneurial risk	Rank	18	13	1	140	5	5	3	3
		Score	62	64	83.1	23.3				
	Companies embracing disruptive ideas	Rank	37	77	1	140	4	3		
		Score	47.8	40.7	77.5	19.9				
	Entrepreneurial capacity	Rank	109	101	1	137	2	2		
		Score	18.4	19.7	83.6	9				
	Level of university and industry research collaboration	Rank	31	118	1	119	4	1		
		Score	54.9	25.3	79.5	22.16				
	Level of economic freedom	Rank	130	111	1	180	2	2		
		Score	55.1	57.3	90.2	5.9				
Density	Cluster development	Rank	36	88	1	119	4	2	5	3
		Score	54.1	40.2	78.4	27.29				
	Presence of technology hubs	Rank	4	2	1	54	5	5		
		Score	30	55	59	0				
	Multistakeholder collaboration	Rank	33	119	1	140	4	1		
		Score	54.4	34.5	79.2	17.4				
	Number of DATs in the country	Rank	113	83	—	—	5	4		
		Score	—	—	—	—				
Finance	Equity financing	Rank	—	—	—	—	—	—		
		Score	348	306	348	1	5	1	4	2
	Domestic credit to private sector	Rank	95	115	1	125	2	1		
		Score	12.28	4.53	100	0				
	Financing for agricultural research and development (R&D)	Rank	—	—	—	—	—	—		
		Score	0.80	0.30	5.80	0.10	1	1		
	Number of equity technology start-up deals in 2018	Rank	—	—	—	—	—	—		
		Score	44	26	44	1	5	3		

continued

TABLE B.1, *continued*

ASSESSMENT AREA	INDICATOR	DATA RANK OR SCORE	RAW DATA				DALBERG-ANALYZED SCORE		AGGREGATE SCORE	
			KENYA	NIGERIA	TOP COUNTRY	BOTTOM COUNTRY	KENYA	NIGERIA	KENYA	NIGERIA
Human capital	Extent of digital skills among population	Rank	43	121	1	139	4	1	3	2
		Score	4.7	3.3	5.8	2.2				
	Labor market for DATs	Rank	60	73	1	140	3	3		
		Score	59.9	58.5	81.9	37.6				
	Future workforce	Rank	105	129	1	140	2	1		
		Score	54.2	38	93.3	31.4				
	Graduate skill set	Rank	56	135	1	140	3	1		
		Score	3.7	2.9	6	2.2				
Infrastructure	Availability of transport (roads, rail, air, sea, and access to water transport)	Rank	82	127	1	140	3	1	3	2
		Score	44.2	29.3	92.1	17.9				
	Reliability of electricity supply	Rank	110	114	—	—	2	1		
		Score	64.5	60.6	66	—				
	Internet access	Rank	125	107	1	150	1	2		
		Score	17%	25.70%	98.20%	5.00%				
	Mobile phone availability	Rank	—	—	—	—	5	4		
		Score	59%	45%	69%	16%				
	Reliability of water supply	Rank	108	137	1	140	2	1		
		Score	85.04	32.03	99.1	8.9				
Regulatory environment	Ease of starting and doing business	Rank	126	120	1	190	2	2	3	2
		Score	82.41	82.97	86.59	25				
	Patent protection	Rank	58	129	1	140	3	1		
		Score	4.4	3.1	6.5	1.7				
	Data protection policies	Rank	—	—	—	—	—	—		
		Score	1	1	5	1	1	1		
	Agricultural regulatory framework	Rank	—	—	—	—	—	—		
		Score	24	17	28	12	5	4		
	Tax-paying environment	Rank	91	157	1	190	3	1		
		Score	72.37	53.53	99.71	0				
	Strength of investor protection	Rank	79	31	1	137	3	4		
		Score	5.3	6.5	8.3	2				
	Suitable markets	Rank	59	48	1	62	1	2		
		Score	32.98	49.24	87.61	20.49				

Source: World Bank based on Dalberg stakeholder interviews.
Note: DATs = disruptive agricultural technologies; — = not available.

TABLE B.2 Summary of findings from the quantitative and qualitative analyses

ECOSYSTEM ASSESSMENT AREAS	FINDINGS FROM STAKEHOLDER INTERVIEWS	CONSOLIDATED FINDINGS
Entrepreneurial culture	• Both Kenya and Nigeria have strong entrepreneurial cultures; however, lack of a sustained commitment—as well as access to networks, mentorship, and role models—hinder the scaling up of innovations beyond the early stage.	• Quantitative analysis shows that both Kenya and Nigeria score average in terms of culture; stakeholder interviews confirm that there is a fundamental entrepreneurial culture that needs to be nurtured. • Kenya and Nigeria rank high on attitudes toward entrepreneurial risk, with scores of 5. However, both countries score low on the level of entrepreneurial capacity and activity, with a score of 2 for both. These scores support the findings from stakeholder interviews that show underlying interest in entrepreneurialism, but a lack of a supporting environment to unleash that interest.
Density	• There are a growing number of technology hubs in both countries; however, many DAT innovators are unable to tap into the resources offered by these institutions.	• Quantitative analysis shows that Kenya ranks high on density, whereas Nigeria ranks only average; stakeholder interviews show that innovators have yet to fully benefit from density. • Many technology hubs (including accelerators, incubators, and co-working spaces) in Kenya and Nigeria are sector agnostic and sometimes fail to cater to the specific needs of DAT innovators, which leads to innovators opting not to be a part of such technology hubs. • Investment in more DAT-specific technology hubs could increase the level of collaboration as more innovators choose to be part of these networks.
Finance	• Access to finance remains a major issue for DAT innovators in both Kenya and Nigeria. • Innovators struggle to access growth capital, especially debt and working capital. • Meanwhile, investors view agri-technology companies as higher-risk investments, given the newness of the space. They would therefore prefer to invest at the later stages of growth of these companies.	• Quantitative analysis shows that Kenya scores high on finance, yet stakeholder interviews indicate that access to finance is one of the biggest challenges facing DAT innovators in Kenya. • The high score of 4 in finance for Kenya is reflective of the funding flowing to the broader technology ecosystem rather than to agri-technology start-ups. Partech Africa found that the majority of equity technology start-up funding flows to financial technology and off-grid technology, with agri-technology still relying heavily on donor and government funding. In 2018, two-thirds of the funding committed to agri-technology innovations was from donors and development partners. • Although the amount of funding and investment deals are comparable in Kenya and Nigeria, Nigeria scores lower than Kenya once the data are normalized to account for the fact that Nigeria is a bigger country with a larger population and GDP relative to Kenya.
Human capital	• Anecdotal evidence from stakeholder interviews shows that Nigeria has better-trained software engineers than Kenya.	• Quantitative analysis shows that Nigeria lags behind Kenya in human capital, but stakeholder interviews show that Nigeria is more likely to have better-trained technology talent. • Nigeria has a larger labor force and is increasingly benefiting from its diaspora moving back to Nigeria. Additionally, Nigeria benefits from the existence of larger agribusinesses and technology companies, which provide the experience and insights of operating a large-scale enterprise. • The factors above increase access to highly skilled talent for the small number of DAT innovations operating in the country relative to Kenya's smaller pool of local talent. • However, it is important to note that Kenya is closing its human capital gap by attracting highly skilled foreign talent with its favorable labor market and innovation density.
Infrastructure	• ICT use and tech adoption are still low among smallholder farmers.	• Kenya and Nigeria lead the continent in mobile and internet connectivity; however, these countries still lag behind global leaders. • Improvements in mobile and internet penetration need to be coupled with enhanced digital literacy to translate into active use. • Digital literacy remains low, particularly for rural populations, which leads to low technology adoption among smallholder farmers.

continued

TABLE B.2, *continued*

ECOSYSTEM ASSESSMENT AREAS	FINDINGS FROM STAKEHOLDER INTERVIEWS	CONSOLIDATED FINDINGS
Regulatory environment	• The Kenyan government has been fairly accommodating of innovative models, allowing these innovations to scale up with limited regulation. The regulatory environment was cited as being fairly beneficial, although inconsistent application can cause uncertainty, which is not attractive to investors. • The Nigerian government has been supportive, but the private sector plays a strong role in steering the direction of DAT innovation.	• Kenya scores better on most of the regulatory environment indicators, which aligns with the findings in the stakeholder interviews.

Source: World Bank.
Note: DAT = disruptive agricultural technology; ICT = information and communication technology.

INTERVIEW QUESTIONNAIRES

Introduction

Thank you in advance for agreeing to be interviewed for the case studies on Disruptive Agricultural Technology (DAT) innovation ecosystems in Kenya and Nigeria, conducted by Dalberg Advisors on behalf of the World Bank Group.

The objectives of the study are the following:

- Understand the status of the DAT innovation ecosystem in Kenya and Nigeria
- Identify scale-up challenges and opportunities for engagement by the public sector, the private sector, and development partners to improve the innovation ecosystem
- Draw key lessons based on the Kenya and Nigeria experience on supporting DAT innovation for other countries in Africa

As an ecosystem actor, your opinions and experiences are extremely valuable toward achieving these objectives. We therefore appreciate your time and input.

Before we begin, there is a chance we may want to use some quotes from this interview to illustrate points in our report. Are you comfortable with us quoting you in our report? [If no] Would you be comfortable if we use your quote without naming you or your organization?

GENERAL INFORMATION

To be filled out ahead of time

INTERVIEWEE DETAILS
Name
Organization
Position
Phone number
Email or other contact info
Date of interview

SECTION 1

Objective: Gain an understanding of the performance of the DAT innovation ecosystem at a high level based on the experiences of the interviewee, and see how perspectives may vary by role in the DAT ecosystem

For innovators

1. What is your DAT innovation and what challenge does it seek to address?
2. Please describe your skills and experiences that contributed to the development of this innovation.
3. Why did you choose to start your business in this sector?
4. Why did you choose to start your business in this country?
5. What is your business model and how have you sustained operations and growth?
6. What challenges or constraints have you encountered while trying to scale up your innovation?
7. What factors can unlock your ability to scale (for example, capital, skilled talent, customer awareness)?
8. What is the next milestone for your DAT innovation in Kenya or Nigeria and how long will it take you to reach it?
9. What constraints do you foresee in scaling up your innovation and how can these constraints be addressed?
10. What do you perceive as success cases or failures in scaling up DATs in Kenya or Nigeria that we may learn from?

For investors and incubators

1. What role do you play in supporting DAT innovations? How and in what do you invest or provide support?
2. [For investors] What influences the choice of what you invest in?
3. [For incubators] What do you look for in identifying DATs to support?
4. What motivated you to start your incubator or accelerator or investments in DATs?
5. How much capital or funding have you committed to DAT innovators?
6. How do you monitor the use of the funding that you give to DAT innovators?
7. What exit opportunities would you like to see in the DAT innovation ecosystem?
8. What factors can unlock your ability to help DAT innovators scale up?
9. What percentage of your portfolio would you be willing to invest in DAT innovations?

10. What do you perceive as success cases or failures in scaling up DATs in Nigeria or Kenya that we may learn from?

For ecosystem enablers

1. What role do you play in supporting the DAT ecosystem? *[If not speaking with a government official]* What role is the government playing in supporting the DAT innovation ecosystem?
2. What are the main priorities for your organization or the government as innovation ecosystem enablers?
3. What policies and regulation exist that are supporting the scale up of DATs?
4. What policy and regulatory constraints are you addressing to promote the growth of DAT innovations?
5. What challenges or constraints have you encountered in creating a supportive enabling environment to scale up DAT innovations?
6. What factors can unlock your ability to help DAT innovators scale up?
7. What do you perceive as success cases or failures in scaling up DATs in Nigeria or Kenya that we may learn from?

SECTION 2

Objective: This section explores the six innovation ecosystem domains that we are assessing as part of the case studies, with the objective of gaining a more in-depth understanding of how the DAT innovation ecosystem is performing across each of these areas in Kenya and Nigeria.

For innovators

Culture

Description of culture: a culture conducive to entrepreneurship includes the presence of role models, public-private cooperation, and promotion of start-up jobs.

1. What are the main cultural barriers facing DAT entrepreneurs and innovators in becoming successful role models?
2. What is your perception of the quality of partnerships and collaborations in the DAT ecosystem?
3. What is the public perception of pursuing entrepreneurship or innovation as a viable career choice?
4. What role can ecosystem actors play in promoting an innovation culture in agriculture, especially among youth?

Density

Description of density: presence of networks that support productive relationships between different actors.

1. Have you used tech hubs (innovators, accelerators, co-working spaces) to get your business to where it is today? If yes, why? If no, why not?
2. Is your business situated in a start-up cluster? If so, what value do you get from this?
3. What is your perception of the quality of start-up clusters present in the country? Can you provide specific examples?
4. What is your perception of the quality of networking assets (for example, events, conferences, networking groups) for DAT innovators?
5. How does the broader innovation ecosystem affect the growth of DAT innovations?

Finance

Description of finance: availability of start-up and venture capital, low-interest loans, and robust public markets, as well as experienced investors.

1. What is your main source of capital currently (for example, personal funds, funds from friends and family, angel investment, venture capital, private equity, debt, equity)?
2. What type of capital does your innovation need to scale up?
3. What do you see as the key challenges affecting access to financial support and capital flows in the DAT ecosystem?
4. What do you see as the main opportunities for strengthening financial support and capital flows in the DAT ecosystem?

Human capital

Description of human capital: availability of technical training, flexible labor markets, diversity of talent.

1. What key skills do you look for in new hires?
2. Why do employees choose to join your company?
3. In your experience, how easy or hard is it to find talent for DATs? To what extent have you had to rely on international hires to supplement local talent? Has this changed over time?
4. Are universities or training institutions adequately preparing graduates with tech-focused and business degrees for companies like yours?
5. What are the main gaps in talent and training that can unlock growth of companies like yours?

Infrastructure

Description of infrastructure: availability of basic infrastructure such as energy, transport, and communication and technology infrastructure such as mobile, broadband, and internet connectivity.

1. Do your customers need access to a feature phone, smartphone, or internet connectivity to use your technology?

2. What are the main gaps in basic infrastructure (for example, transport, power, water, communication) that are affecting the scaling up of your business?
3. What are the main gaps in technology infrastructure (for example, mobile, broadband, and internet connectivity) that are affecting the scaling up of your business?
4. What do you see as the key challenges affecting infrastructure development in the DAT ecosystem?
5. What do you see as the main opportunities for improving the availability of infrastructure in the DAT ecosystem?

Regulatory environment

Description of regulatory environment: supportive policies and regulatory environment, including ease of starting and closing a business, ease of tax procedures and existence of tax exemptions, patent-protection and research and development policies, data policies.

1. What regulatory factors prompted you to build or expand your innovation in Kenya or Nigeria?
2. What are the main regulatory challenges you face in your business operations?
3. How are existing data policies (if any) affecting your business operations?
4. Are you aware of any data policies being drafted that would affect the operation of your business?
5. What do you see as the main opportunities for strengthening the policies and regulations affecting the DAT ecosystem?

For investors or incubators

Culture

Description of culture: a culture conducive to entrepreneurship includes the presence of role models, public-private cooperation, and promotion of start-up jobs.

1. What is your perception of the quality of DAT entrepreneurs and innovators in Kenya and Nigeria?
2. What is your perception of the quality of partnerships and collaborations in the DAT ecosystem?
3. What role can ecosystem actors play in promoting an innovation culture in agriculture, especially among youth?

Density

Description of density: presence of networks that support productive relationships between different actors.

1. What is your perception of the quality of start-up clusters present in the country? Can you provide specific examples?
2. What is your perception of the quality of networking assets (for example, events, conferences, networking groups) for DAT investors and incubators?

3. How does the broader innovation ecosystem affect the growth of DAT innovations?

Finance

Description of finance: availability of start-up and venture capital, low-interest loans, and robust public markets, as well as experienced investors.

1. To your knowledge, what is the estimated funding flow and deal activity for DATs in Kenya or Nigeria?
2. What challenges or constraints have you encountered in financing and supporting the scaling up of DAT innovations?
3. What do you see as the key challenges affecting access to financial support and capital flows in the DAT ecosystem?
4. What do you see as the main opportunities for strengthening financial support and capital flows in the DAT ecosystem?

Human capital

Description of human capital: availability of technical training, flexible labor markets, diversity of talent.

1. In your experience, are universities and training institutions adequately preparing graduates with tech-focused and business degrees for companies like yours?
2. What gaps do DAT innovations face while seeking talent? How can these gaps be addressed?
3. What role can the government or development partners play in strengthening the local talent pool for DAT innovations?

Infrastructure

Description of infrastructure: availability of basic infrastructure such as energy, transport, and communication and technology infrastructure such as mobile, broadband, and internet connectivity.

1. What are the main gaps in basic infrastructure (for example, transport, power, water, communication) affecting the scaling up of DAT innovations?
2. What are the main gaps in technology infrastructure (for example, mobile, broadband, and internet connectivity) affecting the scaling up of DAT innovations?
3. What do you see as the key challenges affecting infrastructure development in the DAT ecosystem?
4. What do you see as the main opportunities for improving the availability of infrastructure in the DAT ecosystem?

Regulatory environment

Description of regulatory environment: supportive policies and regulatory environment, including ease of starting and closing a business, ease of tax procedures and existence of tax exemptions, patent-protection and research and development policies, data policies.

1. What regulatory factors prompted you to invest in DAT innovations in Kenya or Nigeria?
2. What are the main regulatory challenges you face as an agri-technology investor? What are the main regulatory challenges affecting the ecosystem in general?
3. How are existing data policies, if any, affecting your ability to invest in agri-technology innovations?
4. Are you aware of any data policies being drafted that would affect your investment strategy?
5. What do you see as the main opportunities for strengthening the policies and regulations affecting the DAT ecosystem?
6. Are you aware of any government investment promotion strategies for agri-technology innovations?

For ecosystem enablers

Culture

Description of culture: a culture conducive to entrepreneurship includes the presence of role models, public-private cooperation, and promotion of start-up jobs.

1. What is your perception of the quality of DAT entrepreneurs and innovators in Kenya or Nigeria?
2. What is your perception of the quality of partnerships and collaborations in the DAT ecosystem?
3. What role are you playing in promoting partnerships and collaborations in the ecosystem?
4. What role can ecosystem actors play in promoting an innovation culture in agriculture, especially among youth?
5. What role are you playing in advocating for the adoption of disruptive agricultural technologies by farmers, agribusinesses, regional and national governments, and other ecosystem actors?

Density

Description of density: presence of networks that support productive relationships between different actors.

1. What is your perception of the quality of start-up clusters present in the country? Can you provide specific examples?
2. What is your perception of the quality of networking assets (for example, events, conferences, networking groups) for DAT innovators?
3. What is your role in strengthening agri-technology hubs in Kenya or Nigeria? What role can other ecosystem enablers play in strengthening agri-technology hubs in Kenya and Nigeria?

4. How does the broader innovation ecosystem affect the growth of DAT innovations?

Finance

Description of finance: availability of start-up and venture capital, low-interest loans, and robust public markets, as well as experienced investors.

1. What do you see as the key challenges affecting access to financial support and capital flows in the DAT ecosystem?
2. What role do you play in attracting finance for DAT innovations?
3. *[if speaking to a government representative]* Does the government have specific investment promotion strategies to attract investors into agri-technology innovations in Kenya or Nigeria? Has the government committed funding for agri-technology innovations at the regional or national level?
4. What do you see as the main opportunities for strengthening financial support and capital flows in the DAT ecosystem?

Human capital

Description of human capital: availability of technical training, flexible labor markets, diversity of talent.

1. In your experience, are universities and training institutions adequately preparing graduates with tech-focused and business degrees for companies like yours?
2. What gaps do DAT innovations face while seeking talent? How can these gaps be addressed?
3. What role can you play in strengthening the local talent pool for DAT innovations?

Infrastructure

Description of infrastructure: availability of basic infrastructure such as energy, transport, and communication and technology infrastructure such as mobile, broadband, and internet connectivity.

1. What are the main gaps in basic infrastructure (for example, transport, power, water, communication) hindering the scaling up of DAT innovations?
2. What are the main gaps in technology infrastructure (for example, mobile, broadband, and internet connectivity) hindering the scaling up of DAT innovations?
3. What is your role in strengthening critical infrastructure for DAT innovations to scale up?
4. What do you see as the key challenges affecting infrastructure development in the DAT ecosystem?
5. What do you see as the main opportunities for improving the availability of infrastructure in the DAT ecosystem?

Regulatory Environment

Description of regulatory environment: supportive policies and regulatory environment, including ease of starting and closing a business, ease of tax procedures and existence of tax exemptions, patent protection and R&D policies, data policies.

1. What regulations are supporting or attracting DAT innovations to Kenya or Nigeria?
2. What are the main regulatory challenges facing DAT innovators and investors?
3. How are existing data policies, if any, affecting DAT innovations?
4. Are there plans to enact data policies that would affect the DAT ecosystem in Kenya or Nigeria? If yes, how soon can these policies come into effect? At what stage of the policy approval process are they?
5. What do you see as the main opportunities for strengthening the policies and regulations affecting the DAT ecosystem?

ECO-AUDIT

Environmental Benefits Statement

The World Bank Group is committed to reducing its environmental footprint. In support of this commitment, we leverage electronic publishing options and print-on-demand technology, which is located in regional hubs worldwide. Together, these initiatives enable print runs to be lowered and shipping distances decreased, resulting in reduced paper consumption, chemical use, greenhouse gas emissions, and waste.

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This study—which includes a pilot intervention in Kenya—aims to further the state of knowledge about the emerging trend of disruptive agricultural technologies (DATs) in Africa, with a focus on supply-side dynamics. The first part of the study is a stocktaking analysis to assess the number, scope, trend, and characteristics of scalable disruptive technology innovators in agriculture in Africa. From a database of 434 existing DAT operations, the analysis identified 194 as scalable.

The second part of the study is a comparative case study of Africa's two most successful DAT ecosystems in Kenya and Nigeria, which together account for half of Sub-Saharan Africa's active DATs. The objective of these two case studies is to understand the successes, challenges, and opportunities faced by each country in fostering a conducive innovation ecosystem for scaling up DATs. The case study analysis focuses on six dimensions of the innovation ecosystem in Kenya and Nigeria: finance, regulatory environment, culture, density, human capital, and infrastructure.

The third part of the study is based on the interactions and learnings from a pilot event to boost the innovation ecosystem in Kenya. The Disruptive Agricultural Technology Innovation Knowledge and Challenge Conference in Nairobi, Kenya, brought together more than 300 key stakeholders from large technology companies, agribusiness companies, and public agencies; government representatives and experts from research and academic institutions; and representatives from financial institutions, foundations, donors, and venture capitalists.

Scaling Up Disruptive Agricultural Technologies in Africa concludes by establishing that DATs are demonstrating early indications of a positive impact in addressing food system constraints. It offers potential entry points and policy recommendations to facilitate the broader adoption of DATs and improve the overall food system.

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