Working paper 576

Disruptive technologies in agricultural value chains

Insights from East Africa

Aarti Krishnan, Karishma Banga and Maximiliano Mendez-Parra

March 2020

Key messages

- Agricultural technology (AgriTech) is a form of technological innovation, encompassing data-connected devices using information and communications technology, internet and artificial intelligence, agricultural biochemistry and biotechnology, innovative food and farming, farm robotics and automation, and smart warehousing and logistics.
- The adoption of AgriTech depends on the 3Cs: cost – purchasing a specific AgriTech product or asset-specific investment necessary to use the product; complexity of the embedded information and knowledge of a specific AgriTech; and capabilities – the level of skill required by a user to learn how to use the technology.
- The disruptive potential of AgriTech is on a sliding scale. It can be complementary if it supplements existing products, processes or business models, or a replacement/substitute if it displaces existing practices in a sector or value chain and causes behavioural change that ultimately leads to changes in the underlying norms and culture of society.
- Disruption has varied impacts on actors within value chains, with actors like farmers and women experiencing disruption in a different way to multinational companies. We create a new heuristic framework combining the 3Cs and the disruption scale to understand different types of disruption. This will allow policy-makers to classify the disruptive potential of a technology accurately and to provide targeted policy support.
- Disruption in AgriTech has the potential to occur through: (1) increased agricultural productivity in capital and labour; (2) value addition; (3) regional trade and cohesion; (4) skills acquisition and formalisation of jobs; (5) opportunities for youth and women; and (6) redistribution of value. If governed properly, AgriTech can deliver increased equity, expand digital capacities and increase the quality and quantity of jobs.

Acknowledgements

We would like to thank the Enhanced Integrated Framework for funding the project. In particular we would like to thank Mr Ratnakar Adhikari, Ms Annette Ssemuwemba and Mr Simon Hess for all their support through the process and review of the working paper.

We would also like to thank the East African Community, especially Hon. Kenneth Bagamuhunda, Mr Fahari Marwa and Ms Jennifer Gache, for their constant feedback and the time they have spent to share their personal experiences with us.

We could not have completed this report without the support of many individuals and firms interviewed during fieldwork in Kenya, Tanzania, Uganda and Rwanda. We appreciate their time and commitment to our research. We would also like to acknowledge the support given by the governments of Uganda, Kenya, Rwanda and Tanzania: the access and information provided went a long way in improving our analysis.

We also extend our thanks to ODI interns Yun Shi and Yubin Lee for their support in data collection, and Bookie Ezeomah, PhD candidate from the University of Manchester, for her research support. Finally we thank Dirk Willem te Velde for reviewing and providing feedback on earlier drafts.

Contents

List of boxes, tables and figures

Boxes

Tables

Figures

Acronyms

3Cs	costs, complexity and capabilities
AI	artificial intelligence
B2B	business-to-business
B2C	business-to-consumer
EAC	East African Community
EODB	ease of doing business
ERP	enterprise resource planning
FAO	Food and Agriculture Organization of the United Nations
FFV	fresh fruit and vegetables
GPS	Global Positioning System
ICT	information and communications technology
IoT	internet of things
KII	key informant interview
MNC	multinational company
NGO	non-governmental organisation
ODI	Overseas Development Institute
PAD	Precision Agriculture for Development
QR	quick response
R&D	research and development
RFID	radio frequency identification
SMS	short message service
SSA	sub-Saharan Africa
TFP	total factor productivity
UAV	unmanned aerial vehicle
US	United States
VAS	value-added service

Executive summary

Global food demand is expected to increase by between 59% and 98% by 2050 (Elferink and Schierhorn, 2016), as the world population reaches an estimated 9.7 billion (UN DESA, 2019). Food production is especially critical in Africa, as over 70% of the population depend on agriculture for their livelihoods (Biteye, 2016). Against a backdrop of the rapid decline of agricultural productivity, the exclusion of women from the workforce, falling value added within agriculture and the threat of climate change, an increase in the use of agricultural technology or 'AgriTech' can help reduce the threat of livelihood loss and support inclusive economic transformation.

What is AgriTech?

New technology is broadly classified as technological innovations, with the suggestion that technological transitions occur at micro and meso levels, which in turn change socio-technical regimes in economies (Markard and Truffer, 2008). There are multiple types of technological innovations, including AgriTech. AgriTech has the potential to alter the combination of labour, capital and land in agricultural production, and it can bring about changes in agricultural productivity and output.

AgriTech is primarily a combination of (1) hardware for infield and outfield; (2) software and applications; (3) data chains for decision support; (4) processes and assimilation and learning; and (5) monitoring and evaluation.

The combinations of building blocks engender five main categories:

1. **Data-connected devices** (digital ag) using information and communication technology (ICT), internet and artificial intelligence (AI), primarily driven by software development. Examples include agricultural digital platforms ('ag platforms') and farming apps, which are driving e-commerce and the servicification of agriculture.[1] Ag platforms can serve as *marketplaces*, or virtual intermediaries that match buyers and sellers, like M-Farm in Kenya or M-Lamu in Senegal. They can also take the form of business-to-business (B2B) *trading and sharing* platforms, which allow efficient, cheaper and better-quality procurement of inputs such as hardware (tractors, sprayers) and software (including internet of things (IoT) equipment). Farmers can also share knowledge of best practices and post various experiences of participating on ag platforms online which can be shared with other farmers and stakeholders. Another dimension is *horizontal facilities*, including add-ons to extension services such as health services (e.g. iCow) or insurance services (e.g. ACRE Africa) that provide socioeconomic protection to farmers beyond business-as-usual conditions.
2. **Ag biochemistry and biotechnology**, harnessing the strengths of biotech and bioengineering. This entails the scientific improvement of plants, animals and microorganisms through innovations such as genetic engineering, tissue culture, vaccines, agrochemicals, etc. It is targeted at improving agricultural inputs, and is therefore more likely to transform the upstream segment of the value chain, which entails input supply and production.

1 The transformation of existing physical processes or systems into discrete services.

3. **Innovative food and farming**, which unlock new planting systems and food alternatives. For instance, vertical farming (indoor farming), commonly practised indoors and in urban areas, entails the growing of crops (mostly vegetables) in stacks. Companies such as AeroFarms are leaders in this space. They combine geovisual sensors with big data analytics and AI to develop technologically efficient crops.
4. **Farm robotics and automation** drawing on mechanical and electronic engineering coupled with AI. Drones are an example of farm robotics; these unmanned aerial vehicles (UAVs) used in agriculture for monitoring and data capturing. They are often equipped with sensors, which enable the capturing of images to support crop monitoring. Their multi-spectral sensors support precision farming management systems by helping determine areas of a farm that require water or nutrients.
5. **Smart warehousing and logistics** using, for instance, blockchain technology, fleet optimisation software and enterprise resource planning (ERP). For instance, radio frequency identification (RFID) and quick response (QR) codes have been used on agricultural value chains to trace commodities from consumers back to the farm. Blockchains are a more recent innovation, and are decentralised, distributed and public digital ledgers that are used to record transactions in blocks across all computers. Blockchain-enabled platforms can trace a product's provenance, carry detailed attributes for the product in each transaction and ensure its authenticity. They also reduce transaction costs through the disintermediation of transactions in value chains.

Landscape of AgriTech in the East African Community

AgriTech in Africa receives limited funding, owing to constraints relating to the business ecosystem (investment, doing business environment, financial systems), data infrastructure (digital payments, digital ID, digital literacy, digital policies), human capital and connectivity, cloud services and network access (Tsan et al., 2019). The main AgriTech innovations currently adopted in developing countries are digital platforms, such as mobile and web apps used to facilitate information, financial and commodity transaction processes along agricultural value chains. Through a novel dataset collated by the Overseas Development Institute (ODI) of 70 firms in 2018 in the East African Community (EAC), we flesh out the most prevalent types of AgriTech currently, across the five AgriTech categorisations. In the case of each country in the EAC, between 66% and 86% of firms fall within data-connected devices, with ag marketplaces (platforms) the most important, followed by ag biotech (mainly seeds and chemicals) purchased from Monsanto and precision agriculture (use of irrigation and spraying equipment). This implies that, rather than more complex categorisations of ag biosciences, robotics and automation requiring research and development (R&D), it is software, in terms of platforms, and data that take up the largest share of AgriTech in the EAC.

What prevents adoption of AgriTech?

Three key characteristics affect the adoption of AgriTech: **cost** of AgriTech product, **complexity** of AgriTech, and **capabilities** of potential AgriTech users. We call these the 3Cs. It is critical to note that different actors in a value chain adopt, use and diffuse AgriTech in various ways. For instance, micro-enterprises and farmers may find it difficult to adopt AgriTech due to the high costs, complexity and capabilities required; while for a large enterprise it may be less difficult, especially if they already have the capabilities in-house. For the 3Cs:

- **cost** of AgriTech involves the costs of purchasing the product- or asset-specific investments necessary to use the product
- **complexity** of AgriTech relates to the technology intensity of the product and practices to be adopted, and the embedded degree to which complex information and knowledge are transmitted between adopters and innovators – relatively low-complexity products are more likely to replace routine

low-skill tasks, such as selecting the right fertiliser and pesticides, as opposed to high-skill tasks involving sensors and drones for precision agriculture

- **capabilities** of users of AgriTech relates to the level of skill required to use an AgriTech product, which we categorise as two broad types: (1) production capabilities refer to the skills necessary for the efficient operation of a farm/factory with new technologies; and (2) linkage capabilities refer to the skills needed to decode transmitted information from other organisations, allowing diffusion of technology.

What does disruption mean within AgriTech?

The key question within the AgriTech literature is whether such technologies have the potential to be disruptive. However, there are few studies that explain what disruption is or who is disrupted, how value-chain actors are disrupted or the extent to which the potential disruption experienced varies.

Our research finds that disruption is not a linear process and can affect different actors in a value chain differently, from farmers and women to logistic providers to multinational organisations. Disruption is on a sliding scale, it can 'replace/substitute' or 'complement'. Disruption can have a substitution effect if it displaces existing practices in a sector or value chain and causes behavioural change that ultimately leads to changing the underlying norms and culture of society. It is more complementary if it supplements existing products, processes and business models (Christensen and Raynor, 2003; Aker, 2011). This suggests that replacement can make humans performing particular tasks in a specific way redundant; while complementarity facilitates that possible addition of humans performing tasks through different processes that augment current work structures.

Combining the 3Cs and the sliding scale of disruption (complements to substitution) gives us four ideal types of disruptive AgriTech:

1. **Radical** – takes place when products, processes and models kick start new industries (or swallow existing ones), and involves adopting revolutionary technology and changes to behaviour and societal norms).
2. **Architectural** – often described as developing complementary products/processes or modifying existing forms of AgriTech in specific sectors.
3. **Incremental** – the most common form: products and processes are tweaked, improved and complemented by related products and processes.
4. **Frugal** – involves substitution (i.e. by discovering new business models, reconfiguring value chains and redesigning products to serve users who face extreme affordability constraints, in a scalable and sustainable manner).

What are the pathways through which AgriTech may be disruptive?

We identify six pathways through which AgriTech affects value chains and perpetuate disruption. AgriTech can create several paradoxes, generating both positive and negative implications:

1. *AgriTech can lead to increased productivity in capital and labour:* AgriTech potentially facilitates enhancing the strength and cohesiveness of networks within value chains by reducing information asymmetry and encouraging knowledge sharing. Strong networks engender e-trust, which in turn can make the networks increasingly durable and stable. Productivity can be enhanced by digital value-chain management. For instance, within data-connected agriculture, products such as apps tend to complement and not replace processes, and have been classified as architectural and incremental.
2. *AgriTech can lead to value addition and diversification of functions:* disruption can range from radical to incremental. For instance, using remote sensing and land mapping, farmers can begin to grow new products for new markets, thus making the most of the real-time data they obtain in relation to commodity prices, weather and land mapping. While at the same time, the data provided to farmers may be inaccurate due to poor infrastructural support (bad quality bottom-up and top-down enablers) causing significant errors in decision-making

by farmers, and distrust within networks in the value chain.

3. *AgriTech can lead to increased regional trade and cohesion:* research shows that TradeMark East Africa's work in the EAC has resulted in the elimination of 87 of 112 identified non-tariff barriers, in part because of digitalisation. For instance, it supported automation of the application and issuance of certificates of origin in Kenya by the Kenya National Chamber of Commerce and Industry. Apps such as Sauti have improved cross-border trade by providing informal traders with information on regional laws. These technologies generally complement existing processes and do not necessarily change the modus operandi, and thus are primarily classified as architectural and incremental disruptions.
4. *AgriTech can lead to increased skill acquisition and formalisation of jobs:* AgriTech is introducing new skill sets to the agriculture sector in Africa. As agriculture becomes more digitalised and formalised, technical skills such as the operation of drones, platforms and automated systems will be increasingly sought after. These types of disruption may range from frugal, involving low costs but providing new markets and new ways of trading with different countries across the border; to more architectural, complementing processes, but expensive and complex.
5. *AgriTech can increase opportunities for youth and women entrepreneurs:* AgriTech has opened up opportunities for educated youth to participate in agriculture by appealing to the 'tech-savvy' nature of young East Africans who are currently innovating to add value to agricultural value-chain activities. Secondary data collected suggests the average age of 'agri-preneurs' is between 29 and 34 in the EAC; however, there are generally far fewer women than men.
6. *AgriTech can be a means to improve redistribution of value:* technology, by its nature, supports the creation of value; however, disruption comes at a cost to agency, in terms of the inevitable displacement of actors or the unplanned restructuring of business models. While disruptive innovation increases the competitive advantage of innovators and adopters, it can also be competency-destroying to other value-chain actors unable to adopt AgriTech. There is a need to create a global reporting standard for AgriTech products, so as to be able to benchmark results, integrating data with fiscal policy (taxation) and mapping the creation of new global wealth chains. This will make it possible to understand areas where there is 'surplus value capture', not only as money but also as learning and knowledge accumulation. The understanding of where 'surpluses' are being created can help identify potential spaces for redistribution.

While AgriTech has the potential to transform trade, work opportunities and enhance capacities, if unregulated or not governed properly, it can exacerbate inequalities. For example, rather than providing a potential for increased regional trade cohesion it can exacerbate digital divides and compound job losses. It can also be used as a tool for further marginalization of women and youth rather than increased empowerment. Smart Warehousing can be hacked causing logistical delays and income reduction.

This working paper is an output of the project 'Disruptive potential of AgriTech in East Africa: implications for regional integration and inequality'. The overarching aim of the project is to unpack the implications of the digitalisation of agriculture, especially through the use of ag platforms.

1 Introduction

1.1 AgriTech proliferation and adoption in East Africa

Global food demand is expected to increase by anywhere between 59% and 98% by 2050 (Elferink and Schierhorn, 2016), as the world population reaches an estimated 9.7 billion (UN DESA, 2019). Food production is especially critical in Africa, as over 70% of the population depend on agriculture for their livelihoods (Biteye, 2016). Livelihood loss is compounded by the rapid decline of agricultural productivity, a fall in value added within agriculture and the threat of climate change. Additionally, agriculture over the last decade has been marginalizing women and youth from the work force (Barrientos, 2014).

Increased use of robotics, automation and precision agriculture can provide opportunities to solve some of these grand challenges. Technology in food production constitutes one of the most powerful solutions to the challenges of the future. For instance, technology applied within the genetics of seeds makes plants more resilient to drought and increases yields. The use of sensors and satellite and drone images allows producers to monitor crop status and act when necessary. Connectivity between producers and buyers reduces transaction costs and increases efficiency in the distribution of products. Robotics within food manufacturing is leading to increased productivity and lower consumer prices.

New technology is broadly classified as technological innovation, which suggests that technological transitions occur at micro and meso levels, which in turn change socio-technical regimes in economies (Markard and Truffer 2008). There are multiple types of technological innovations, including AgriTech. AgriTech has the potential to alter the combination of labour, capital and land in agricultural production, and it can bring about changes in agricultural productivity and output.

There are various types of AgriTech innovations. These range from biotech to improved inputs (seeds, feeds, agro-chemicals, vaccines), digital technologies that facilitate the performance of agricultural value-chain activities (Deichmann et al., 2016) to farm robotics and automation. AgriTech provides actors within the agricultural industry with innovative products and data to improve productivity, efficiency and sustainability.

As a consequence of increasing AgriTech proliferation, the way economic actors participate in the production and trade of agricultural products has changed significantly. New technologies alter the combination of labour, capital and land in agricultural production. The business-to-consumer (B2C) direct relationship that technology allows leaves traders and other intermediary actors without a raison d'être. This process is often defined as 'disintermediation' (Andal-Ancion et al., 2003). While AgriTech has the potential to open new doors to increasing productivity and value addition, it can simultaneously deepen inequalities and cause further marginalisation of the poorest. AgriTech diminishes the importance of physical asset ownership and creates opportunities linked to increased ag-servicification, which allows for increased value capture. Technology can allow countries and regions to leapfrog and gain new competitive advantages. AgriTech is of particular relevance to the EAC, as agriculture and food are the important sectors of the region's economies after natural resource extraction.

While these technologies are often labelled as disruptive or said to have 'disruptive potential', limited research has been conducted on what this disruptive potential is, who is disrupted, how disruption occurs and to what extent disruption differs. Understanding whether a 'disruptive spectrum' exists is critical to policy, as it can support the development of policies that can deter negative aspects of disruption or facilitate positive disruption potentials.

1.2 AgriTech, disruption and pathways to transformation

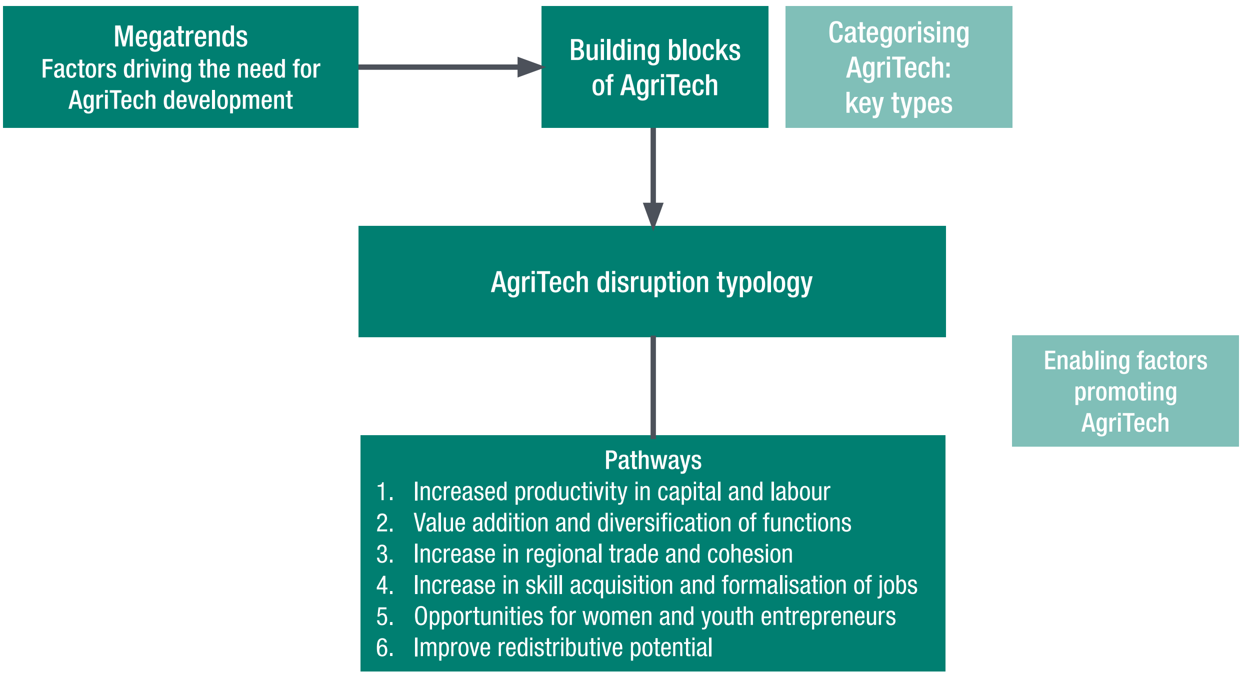
This working paper is part of the 'Disruptive potential of AgriTech in East Africa: implications for regional integration and inequality' project. The overarching aim is to unpack the implications of the digitalisation of agriculture, especially through the use of ag platforms. Briefly, digital ag platforms are defined as technology architectures that support further development of mobile and web applications, serving as a two- or multi-sided market that brings together two or more users in agriculture.

The first in a series, this working paper aims to provide the conceptual underpinnings of AgriTech. It addresses the following key questions:

- What is AgriTech?
- What prevents adoption of AgriTech?
- What does disruption mean within AgriTech?
- What are the pathways along which AgriTech may disrupt livelihoods and support transformation?

The paper is structured as follows. Chapter 2 discusses the megatrends driving the need to develop AgriTech, especially within the EAC. Chapter 3 examines what AgriTech is – its main building blocks and types – and brings to the fore key characteristics of AgriTech that promote uptake and adoption. Chapter 3 also presents the current landscape of AgriTech in the EAC. Chapter 4 conceptualises disruption within AgriTech and presents a typology – with examples from the EAC – along with providing a discussion on the key wider enablers that engender AgriTech adoption. Chapter 5 presents six key pathways along which AgriTech can disrupt the 'norm' of how agricultural value chains currently function, and explores the different implications across the various actors who participate in the value chain. Chapter 6 offers a conclusion and suggests potential next steps.

Figure 1 Report structure and conceptual underpinnings of AgriTech and disruption



Source: Authors' elaboration

2 Megatrends driving the need for AgriTech development

While the prevalence and penetration of technology in agriculture has been driven by advancements in digital technologies and ICT infrastructure such as the internet, digital platforms, drones and precision farming systems (Tey and Brindal, 2012; Deichmann et al., 2016), the main need for the rapid advancement in and adoption of AgriTech is attributed to eight megatrends.

Trend 1: Rising population and pressure on food systems and food security. Sub-Saharan Africa (SSA) in particular already faces the greatest food security risk of any region: it is expected that by 2050 its population will have increased 2.5-fold, and that demand for staple cereals will have approximately tripled (PwC, 2018).

Trend 2: Increasing urbanisation. According to the World Development Indicators, on average, urbanisation in East Africa has increased by 3.5% over the past 20 years (World Bank, n.d.). This has been compounded by an ever-increasing population moving away from agricultural production towards urban settlements. This in turn reduces overall domestic production, increasing pressure on food security.

Trend 3: Poor value addition and low participation in global value chains. There is significant dependence on agriculture in terms of participating in value chains in the EAC. Data on sectoral backward and forward linkages for EAC countries from the Export Value Added Database (EVAD, n.d.) and the World Integrated Trade Solution database (WITS, n.d.), calculated the total domestic value added embodied in a sector's exports. It is observed that, in all EAC countries, primary agriculture ranks in the top five sectors exporting value added in terms of backward linkages. While in terms of forward linkages, in all EAC countries considered, primary agriculture ranks at the top in terms of exporting value added.

Trend 4: Increasing regional trade and gaining competitive advantages. The African Union has seen the push for increasing regional trade as an alternative to exports to the Global North as critical to the future of Africa. The Malabo Declaration's priorities are to treble intra-regional trade in agricultural products by 2025 and harmonise trade barriers across the continent (AU, 2014). This will involve improving the connectivity of products to various markets and strengthening the efficiency, quality and transparency of value chains, ultimately making cross-border trade across markets more attractive and less risky.

Trend 5: Gender inequity. According to the United Nations Human Development Index, East African countries have some of the lowest gender equality index rankings (UNDP, n.d.). Studies point to the frequent exclusion of women from the workforce and cite the 'invisibility of women', referring to women's unwaged farm labour and their lack of land rights (Barrientos, 2014; Kabeer, 2019). Women are shown to have a higher propensity to produce better-quality food and to spend on more diverse diets for children, thereby promoting food security (Quisumbing et al., 1996; Bay, 2019).

Trend 6: Lack of nutrition. East Africa experiences chronic undernourishment, and around 35% of children under five were stunted in 2016 (Danaei et al., 2016). Access to diverse diets is key to healthy lives and increasing overall productivity.

Trend 7: Threats of climate change and resource scarcity. This is one of the biggest factors driving the need to produce more food with fewer resources for the growing East African population (Mwangi and Kariuki, 2015). Climate variability and extremes (droughts, floods) lead to losses related to assets, incomes, livelihoods, crop quality and productivity, and ultimately affect the ability to produce food. Sudden increases (or decreases) in temperature and rainfall directly affect crop production by reducing productivity and yields by between 5% and 40% in semi-arid regions of Kenya (Lobell and Field, 2007; Herrero et al., 2010), diminish plant health through increased pest attacks affect plant defence mechanisms (Iizumi and Ramankutty, 2015) and enable growth of new pathogens, amplifying disease probability. Any fall in the quality of natural resources has significant consequences because only 12% of East Africa's total land area is considered to have high potential for farming (Kabubo-Mariara and Karanja, 2007). For instance, the Kenyan National Climate Change Action Plan 2013–2017 puts the annual burden of climate variability and extremes at 2.6% of the country's gross domestic product.

Trend 8: Growth of ag servicification and threat of deindustrialisation. Data on the EAC countries from the World Development Indicators on sectoral value added as a share in gross domestic product reveals that value-added services (VASs) increased in Burundi, Rwanda and Uganda in the period 2000–2017; although they declined in Kenya and Tanzania, their average share in the EAC was 43.8% in 2017 (World Bank, n.d.). This is higher than the average manufacturing value added (7.5%) and agricultural value added (29.7%) in the EAC for 2017. There are growing concerns of African countries experiencing premature deindustrialization (Rodrik, 2016) as a result of global changes, changes in structural demand, technological progress and, more recently, digital progress.

Overall, each of these megatrends highlights that there are considerable changes occurring within economies in the EAC, and that there is a need to capture more value, gain competitive advantage, support gender empowerment and diversify diets to increase nutrition, while simultaneously improving resilience to climate change. AgriTech seems to offer technological solutions that can drive sustainable intensification, precision agriculture, increase productivity and efficiency and create jobs for transformation. We explore the role AgriTech plays in development in further detail throughout this working paper.

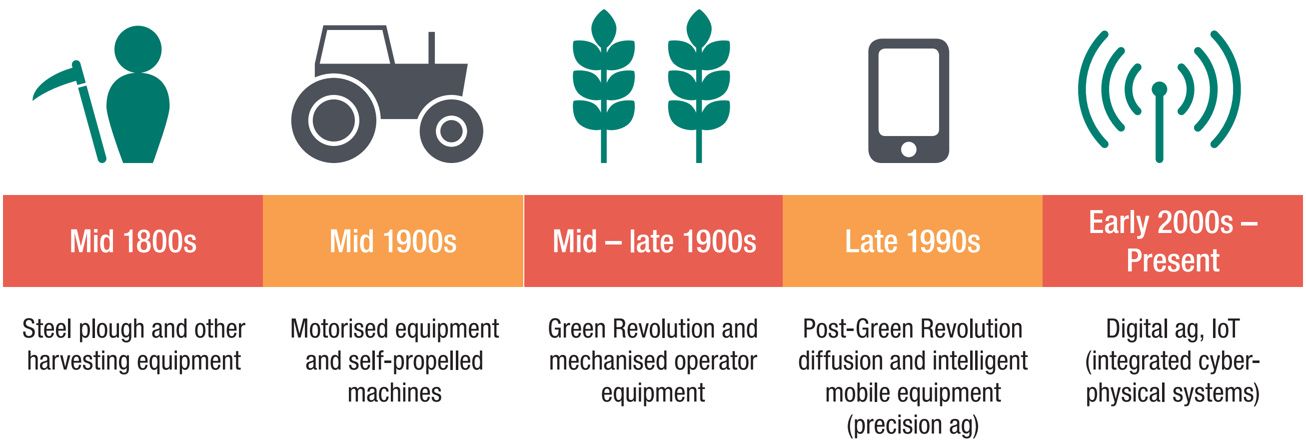
3 AgriTech in value chains: definition, types and characteristics

In this section we briefly outline what AgriTech is, discuss the key building blocks of AgriTech and develop a categorisation of different types of AgriTech.

AgriTech represents a type of technological innovation with the potential to bring about improved agricultural techniques and practices for increased agricultural productivity and output (Jain et al., 2009).

The evolution of AgriTech is explained by five stages of mechanisation coupled with the Green Revolution. Agricultural mechanisation was enabled by technologies that created value in agricultural production practices through the more efficient use of labour, the timeliness of operations and more efficient input management with a focus on sustainable high-productivity systems. As illustrated in the timeline in Figure 2, in developed countries in the early 19th century, tools such as steel-surfaced ploughs replaced animals, followed by the use of tractors in the middle of the 20th century, leveraged a growing oil economy, which led to the development of several variants, including combine harvesters. While much of the mechanisation growth was centred around developed countries, the mid-to-late 1900s saw the rise of the Green Revolution. This involved developing countries publicly investing in genetically improved crops (e.g. high-yielding variety seeds), and adopting the scientific advances already made in the developed world for the major staple crops – wheat, rice and maize. Research has shown mixed effects on productivity, food prices and nutrition (Webb et al., 2017).

Figure 2 Evolution of AgriTech



Source: Authors' construction – adapted from Reid (2011) and Pingali (2019)

The late 1990s saw the growth of new institutional configurations, with the involvement of R&D organisations such as CGIAR generating technological spillovers for countries that underinvest in agricultural research, because they are unable to capture all of the benefits of those investments. Simultaneously, the increased prevalence of mobile phones and the development of code division multiple access (CDMA) and Global System for Mobile (GSM) communications technology and the internet fuelled the speed of transmission of information and knowledge. Development in electronically controlled hydraulics and power systems, coupled with public access to global navigation satellite system technologies, laid the foundations for the development of precision agriculture. This uses satellite position data, remote sensing devices and proximal data-gathering technologies to enable an information-based decision-making approach to farm management to optimise returns on inputs (Zhang et al., 2002).

Since the early 2000s, automation and communication (collection, transfer and management of information by means of ICT) has facilitated the combination of the cyber, or digital, domain with the physical domain to advance precision agricultural production systems. For instance, the use of Global Positioning System (GPS) technology and high-precision accuracy through various reference signal configurations (e.g. multiple satellite systems, sensor fusion with complementary sensors) has enabled decimetre-level accuracy. Additionally, the past decade has shown a rise in unmanned automation, capable of driving complete field patterns under autonomous management of the tractor-implement functions without frequent operator intervention. This, combined with IoT[2] inter-machine communication and AI (using machine learning), can make it possible to collect, store and transfer information about the crop, field and machine state at the time of field operation, and to learn from the agronomic data (Tsan et al., 2019).

While several AgriTech innovations have been developed and deployed in agricultural production in developed regions, resulting in rapid development of the agriculture sector in the Global North, agriculture in low-income economies remains largely underdeveloped and characterised by a low level of technology adoption (Kuijpers and Swinnen, 2016). These are the result of significant access barriers cause by the fragmentation of land, the costs of adopting new machinery, the complexity of learning and a lack of explicit technology transfer by developed countries. The data in Table 1 shows that, in the last two stages of AgriTech evolution, SSA total factor productivity (TFP)[3] and output change kept par with those of Asia until 2000, after which there was a significant fall in TFP. Parallels can

Table 1 TFP, output and food security

Region	Variable	1991–2000	2001–2010	2010–2014
SSA	Output growth (%)	3.3	3.8	2.9
	TFP growth (%)	2.1	0.8	0.2
	Food security score*	–	–	38.1
Asia and the Pacific	Output growth (%)	3.7	3.5	2.7
	TFP growth (%)	1.5	1.3	1.5
	Food security score*	–	–	55.9

Note: *2014 data.
Source: Adapted from Global Food Security Index, International Food Policy Research Institute

2 The Internet of Things, or IoT, is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.

3 TFP is an indicator of how efficiently agricultural land, labour, capital and materials (agricultural inputs) are used to produce a country's crops and livestock (agricultural output). It is calculated as the ratio of total agricultural output to total production inputs. These TFP estimates were generated using the most recent data on outputs and inputs from the Economic Research Service of the United States (US) Department of Agriculture, an internationally consistent and comparable dataset on production and input quantities built using data from the FAOSTAT database of the Food and Agriculture Organization (FAO), supplemented with data from national statistical sources.

be drawn with the food security score,[4] which indicates a significantly lower level of food affordability, availability, quality and safety in SSA compared to Asia by 2014 (IFPRI, 2019).

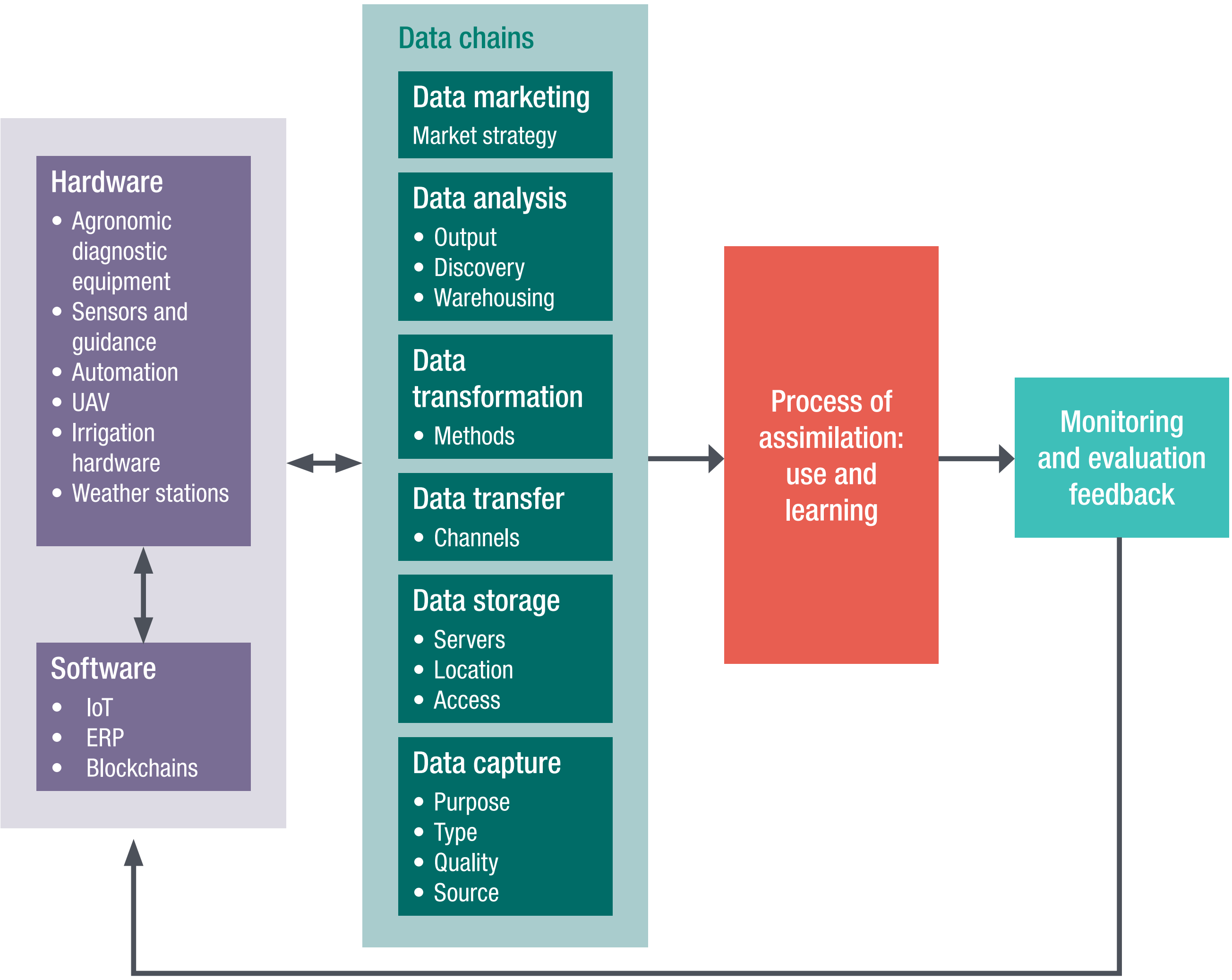
3.1 Types of AgriTech: the building blocks

The building blocks of AgriTech are (1) hardware for infield and outfield; (2) software and applications; (3) data chains for decision support; (4) processes and assimilation and learning; and (5) monitoring and evaluation. Figure 3 depicts each of these and their key components.

Hardware is defined as the machines, wiring and other physical components of an electronic and mechanical system. AgriTech hardware consists of infield tech, including agronomic *diagnostics equipment* (e.g. new types of portable soil, crop and agriculture input testing tools):

- Sensors used for mapping provide spatial and proximate information. Location sensors, for instance, use GPS tracking; optical sensors use light to measure soil properties; electrochemical sensors measure soil nutrient levels; and 'in situ' soil moisture sensors unearth soil water levels.

Figure 3 Building blocks of AgriTech



Source: Authors' elaboration

4 The Global Food Security Index considers the core issues of affordability, availability and quality and safety across a set of 113 countries. The index is a dynamic quantitative benchmarking model constructed from 28 unique indicators. It measures the drivers of food security across both developing and developed countries.

- Automation occurs in tractors, harvesting (picking fruit and vegetables), precision pruning, watering and crop trimming, as well as automated climate control for cool chain logistics.
- Drones are UAVs used in agriculture for monitoring and data capturing. They are commonly equipped with sensors that enable the capturing of images that can support crop monitoring.
- Guidance hardware for accurately triangulating GPS and other connected devices, which are compatible with older devices, provided by companies such as AgJunction, GK Technology and Trimble; and imagery systems, which translate satellite data into precise images (e.g. geovisual analytics).
- Variable-rate tech applications enable producers to vary the rate of crop inputs. They combine a variable-rate control system with application equipment to apply inputs at a precise time and/or location to achieve site-specific application rates of inputs, which are crucial to improving the efficiency of input use.
- Low-cost hyper-local weather stations and weather monitoring devices improve the precision of capture and enable heightened sensing of weather changes.
- Irrigation hardware includes not only irrigation equipment such as centre pivot and linear irrigation systems, drips, sprinklers, pumps and travelling irrigation lines, but also distributional watering systems for spreading and directing water and liquid chemical flows to prevent displacement and run-off.

The next building block comprises **software and applications**, which are the predominant focus of Industry 4.0. Most notably, this includes:

- IoT – a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. This is central to sensor-driven interactions among hardware.
- A host of crop and farm management and monitoring software that allows the syncing of hardware devices to mobiles, tabs and laptops to collate multiple streams of data related to growth progress of crops, pests, diseases, weather, quality checks and financial and farm labour management. These are ERP systems software,[5] and can integrate planning, purchasing inventories, sales, marketing, finance, human resources and more. Another important software category comprises apps, especially farmers' apps, which form important ag platforms for gathering information on market prices, sharing knowledge among peers through in-app messaging and trading products by connecting to buyers.
- Traceability for adherence to food standards, quality management and digital wallets that provide agro-loans and expense accounts to farmers that is frequently blockchain-enabled. Blockchains are decentralised, distributed and public digital ledgers that are used to record transactions in blocks across all computers. This prevents records from being altered retroactively, as such an alteration would involve significant time and cost implications, as the alteration would need to occur across all subsequent blocks. Digital ledgers of economic transactions can be programmed to record nearly all forms of transactions.

The third building block of an AgriTech system is **data chains**. These embrace a life cycle spanning data capture, storage, transfer, transformation, analytics and marketing. While data capture and storage are completed through hardware, data transfer and transformation occur through software programmes. Data analytics are a critical component of integrating hardware, while software to create data-connected AgriTech is central to the growth of digital technologies. Big data and data science entail the collection of a huge volume and variety of data at great speed through a diverse range of sources. Data science attempts to filter, prepare and analyse the complex

5 ERP is business process management software that allows an organisation to use a system of integrated applications to manage the business and automate many back-office functions related to technology, services and human resources.

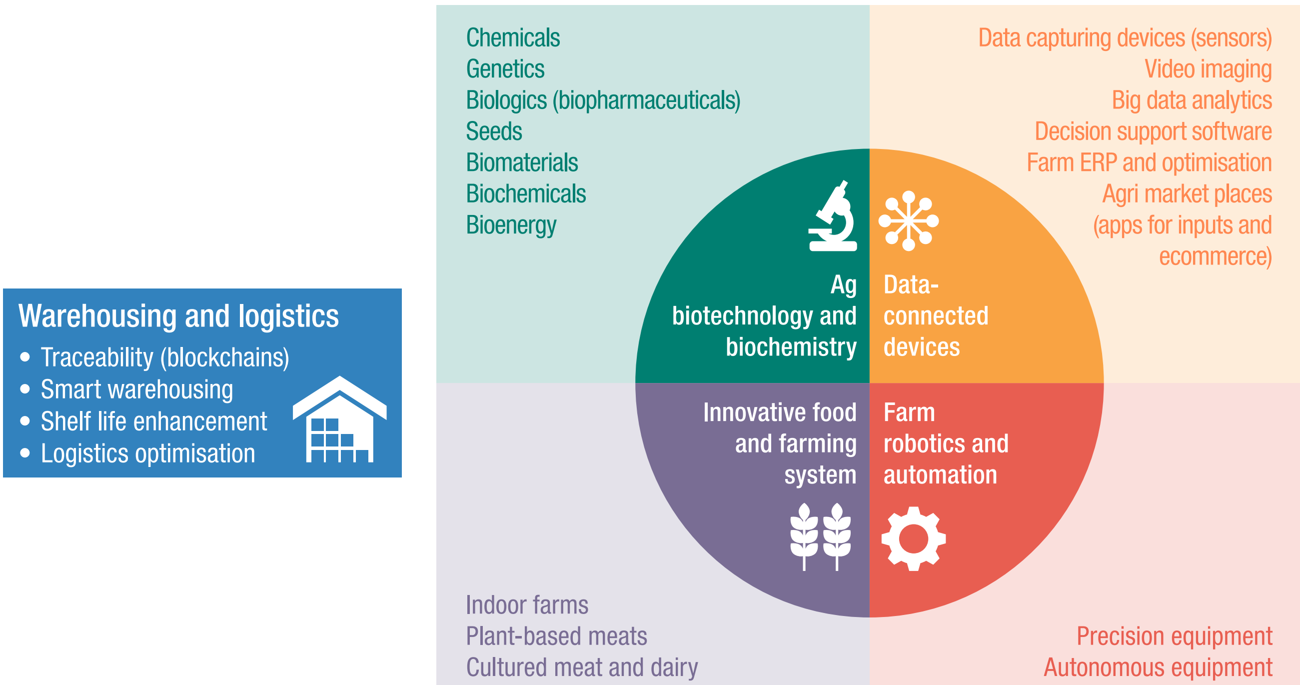
patterns from big data and develop models. Cloud computing is one of the most common models used to filter and provide trends on big data.

Another important category of software and data is AI, which purports to make machines emulate human functioning, with the degree to which an AI system can replicate human capabilities used as the criterion for determining the types of AI. AI performs routine tasks within agriculture; for instance, routine AI is used in Makerere University's White Fly Count App,[6] which counts the number of whiteflies on leaves. These are 'reactive AI', which do not learn but respond to stimuli. Another form of AI, 'limited memory', uses past memories to improve responses (Joshi, 2019). For instance, IBM's Hello Tractor in Kenya provides driverless tractor services on farmers' pooled land. Data analytics facilitates the data discovery, which involves interpreting masses of data and sharing this through data-driven services; as well as data warehousing, which makes it possible to connect data to decisions and run loops, to learn and receive continuous real-time decision support (Wolfert et al., 2017).

The next component is **assimilation and absorption**. As indicated in Figure 4, AgriTech needs to be codified into languages that are comprehensive and targeted to users (e.g. farmers and youth) in specific regions, who will use AgriTech for specific purposes that benefit them. How fast and how successfully local users can internalise and translate transferred knowledge and innovations into their own capability through learning will largely be determined by their underlying capacity to absorb new knowledge and willingness to put in effort (Cohen and Levinthal, 2000; Ernst and Kim, 2002). Therefore, various AgriTech products have different levels of uptake and assimilability for different users. The next section discusses the key characteristics AgriTech products need to ensure adoption and assimilation, which is key to the long-term sustainable, use of products.

Finally, **monitoring and evaluation** is necessary for mapping the performance of specific AgriTech tools and will generate data for feedback and improvement and make it possible to tailor the AgriTech to specific socio-economic and environmental contexts. This means moving away from a technologically deterministic structure

Figure 4 AgriTech categorisations and related products



Source: Authors' construction

6 Available at: https://play.google.com/store/apps/details?id=aidev.cocis.makerere.org.whiteflycounter&hl=en

of just ‘pushing a new AgriTech innovation’ to more participative and co-produced AgriTech innovation that facilitates a win-win situation.

3.1.1 AgriTech categories: classification by key technologies used

The combinations of hardware, software, data chains, assimilation and monitoring engender five main categories of AgriTech. Each category is selected based on the main type of technology. Within each category we provide examples of different AgriTech products that use the main AgriTech category technology (see figure 4). We also provide some prevalent illustrations of each category of AgriTech in East Africa, to generate a landscape of the different existing AgriTech types. AgriTech in East Africa is discussed in more detail in Chapter 4.

The five categories we derive are based on the overarching technology used:

- **data-connected devices (digital ag)** using ICT, internet and AI, primarily driven by software development (main building blocks: software and data)
- **ag biochemistry and biotechnology**, harnessing the strengths of biotech and bioengineering (main building blocks: hardware, software and data)
- **innovative food and farming**, which unlock new systems of plantation and food alternatives (main building blocks: software and data)
- **farm robotics and automation**, drawing on mechanical and electronic engineering coupled with AI (main building blocks: hardware, software and data)
- **smart warehousing and logistics**, consisting of the use of blockchains, fleet optimisation software and ERP (main building blocks: hardware, software and data).

This is not to say that these categories should be viewed in isolation, as they are all deeply interconnected, especially when considering a full value chain from the stage of pre-production, production, harvesting and post-production, logistics and retail. For instance, the use of ICT, the internet and IoT cut across these categories. However, we present this categorisation for simplicity and for the purpose of illustrating the array of different forms of AgriTech that range from digital to biochemistry. Much of the focus within the AgriTech space has been on data-connected devices in East Africa (discussed later in this chapter and in chapter 4).

Data-connected devices: example of ag platform apps

This involves farm data collection, aggregation and analysis to support informed decision-making in agricultural production through the use of innovation such as remote sensing. These technologies enable data capture across small, medium and large fields and support the identification of problem areas within a farm that require targeted input supply and further monitoring. Also, decision support software such as precision farming information systems have become an integral part of large-scale farm management systems supporting informed decision-making on the use of inputs in agricultural production for output optimisation. These solutions encompass a wide variety of digital technologies and tools, including everything from agronomic advice and information delivered via short message services (SMS) and interactive voice response (IVR) to smartphone applications that link farmers to multimedia advisory content, farm inputs and buyers (Tsan et al., 2019). There are business solutions that rely on sophisticated software and data analytics platforms to help agribusinesses manage their smallholder supply chains; financial technology solutions that digitise payments or utilise satellite and weather data to analyse the creditworthiness of farmers and deploy new types of agricultural insurance; and agriculture dashboards and decision tools for policy-makers.

A prevalent type of AgriTech in SSA is agricultural digital platforms and farming apps, which are driving e-commerce and the servicification of agriculture in developing regions. Multi-stakeholder alliances are an increasingly popular approach to enhance collaboration and innovation within the agricultural research for development sector (Neef and Neubert, 2011; Schut et al., 2018). They are promoted to bring together groups of individuals (who often represent organisations) with different backgrounds, expertise and interests – farmers, traders, food processors, researchers, government officials – and to provide them with a space for learning, action and change (World Bank, 2016). The fact that previously disconnected stakeholder groups come together to diagnose agricultural and broader livelihood problems, identify opportunities and find ways to achieve their goals is among the main benefits of innovation platforms.

Digital platforms have been defined as technology architectures that support further development of mobile and web applications, serving as a two- or multi-sided market that brings together two or more users with a similar interest (Gawer, 2014). Digital platforms are commonly conceptualised based on two typologies. The first is digital innovation platforms – these are used by innovators as the foundation for developing third-party applications for a range of services. These are often referred to as base technologies for platforms that allow modular building of more complex software onto it. The second type are digital transaction platforms, which are effectively the third-party applications (apps) developed primarily to facilitate transactions between two or more user groups (Koskinen et al., 2018). Upcoming innovators in Africa, who tend to be resource constrained, are currently adopting digital innovation platforms as low-cost innovation platforms and attempting to create third party apps, such as mobile and web apps, that facilitate B2B and B2C exchange across agricultural value chains (Ahuja and Chan, 2016; Howell et al., 2018).

These ag platforms can be characterised by their scope. This refers to the breadth of functions and processes that characterise the ag platforms. For instance, ag platforms can serve as 'marketplaces', or virtual intermediaries that match buyers and sellers, like M-Farm in Kenya or M-Lamu in Senegal. Their scope also includes trading and sharing platforms, which allow B2B renting of inputs such as hardware (tractors, sprayers), software (including IoT equipment) and knowledge sharing. Farmers can post various hardware, software and experiences online, which they can lease/sell to other farmers (such as WeFarm Kenya). Another dimension is horizontal facilities, including add-ons to extension services such as health services (e.g. iCow) or insurance services (e.g. ACRE Africa) that provide socioeconomic protection to farmers beyond business-as-usual conditions. Scope could also refer to platforms that arise through crowd-funding schemes, which in turn need to cater to the priorities of different owners. Such platforms can start as informal networks and some may transition into more formalised structures, such as public–private partnerships or cooperatives, with the goal of becoming self-sustaining (Schut et al., 2018).

The mainstreaming of digital platforms in developing country agricultural value chains is enhancing the servicification of agriculture in these regions, transforming rural agriculture from a land- and labour-driven sector to a services-driven sector. This is opening it up to new stakeholders who provide VASs that improve the efficiency of performing transactions in agricultural value chains. Future ODI papers in the Disruptive AgriTech series will explore ag platforms in more detail.

Agricultural biochemistry and biotechnology: examples of generic engineering and vaccinations

Agricultural biotechnology entails the scientific improvement of plants, animals and microorganisms through innovations such as genetic engineering, tissue culture, vaccines and agrochemicals. It targets the improvement of agricultural inputs and is therefore more likely to transform the upstream segment of the value chain, which entails input supply and production. Examples include:

- Genetic engineering – also known as genetic modification or genetic improvement – involving the transfer of desirable characteristics from one organism (plant, animal or microbe) to another. In agriculture, it is carried out to improve crop and animal resistance to pests and disease, with the aim of improving agricultural productivity.
- Vaccines derived from biotechnology used in animal production to protect animals against infectious diseases that lead to fatality in animal husbandry.
- Tissue culture involving plant reproduction using disease-free plant parts within a controlled environment. It is commonly carried out in the production of pineapple, citrus and avocado.

Innovative food and farming systems: example of vertical farms and hydroponics
Innovations in food production and farming systems are geared toward sustainably intensifying agricultural production through innovative models that support the production of more food with fewer resources. For instance, vertical farming (indoor farming), commonly practised indoors and in urban areas, entails the growing of crops (mostly vegetables) in stacks. Vertical farming agricultural systems support sustainable intensification of agriculture by using less land and water to grow food within a controlled environment, especially where there is limited land availability – such as in urban areas. Hydroponics is intended to reduce agriculture's impact on the environment through preventing land degradation caused by intensive agricultural systems. Also known as 'soil-less agriculture', hydroponics entails the cultivation of crops in minerals and water – in the absence of soil and on relatively smaller land parcels. These innovative farming systems improve agricultural productivity and could transform the upstream segment of agricultural value chains.

Farm robotics and automation: examples of drones
Farm robotics and automation make use of digital technologies such as drones and other autonomous equipment to monitor and remotely control agricultural processes. These innovations support precision agriculture systems, ensuring agricultural inputs are applied efficiently in areas where they are specifically required, reducing waste and improving agricultural productivity. Drones are UAVs used in agriculture for monitoring and data capturing. They are often equipped with sensors that enable the capturing of images to support crop monitoring. Their multi-spectral sensors support precision farming management systems by helping determine areas of a farm that require water or nutrients. Farm robotics and automation innovations have the potential to transform the upstream segment of the value chain by improving the efficiency of on-farm agricultural production.

Warehousing and logistics: examples of blockchains for traceability
Smart warehousing and logistic technologies support value-addition activities in agriculture such as commodity traceability, crop storage, shelf-life enhancement, logistics optimisation and agricultural produce processing. For instance, RFID and QR codes have been used on agricultural value chains to trace commodities from consumers back to the farm. A more recent innovation, blockchains are decentralised, distributed and public digital ledgers that are used to record transactions in blocks across all computers. This prevents records from being altered retroactively, as such an alteration would involve significant time and cost implications, as the alteration would need to occur across all subsequent blocks. Digital ledgers of economic transactions can be programmed to record nearly all forms of transaction. These are relevant because they enhance traceability requirements and help farmers adhere to standards. Blockchain-enabled platforms can trace a product's provenance, carry detailed attributes for the product in each transaction and ensure its authenticity. They also reduce transaction costs through the disintermediation of transactions in agricultural supply chains, and the use of smart contracts enables frictionless and real-time payments for agricultural financial services. This provides for real-time management of the overall value chain (Deloitte, 2017).

3.2 Characteristics and qualities of AgriTech to promote adoption

The previous sections examine five categorisations of AgriTech, which are driven by key technologies used within each category and a combination of building blocks: hardware, software and data. At the outset, these explain the various AgriTech products that exist. But it is also important to understand the main characteristics or attributes that prompt adoption of AgriTech. The different categorisations of AgriTech will have embedded within them *objective criteria that identify a feature or quality of an AgriTech category and product*. We identified three characteristics, the 3Cs – costs, complexity and capabilities. Each of the 3Cs helps to gain an understanding of the internal structure of each category of AgriTech, which in turn helps examine how 'easy' or 'difficult' it is to adopt different types of AgriTech. This is important, as it encompasses under-resourced and vulnerable producers, women, micro-enterprises and youth in agro-value chains in East Africa, who find it challenging to adopt AgriTech when it is too costly and complex, and thus require a more effective skillset. In this section, we explain each of the 3Cs and link them to the overall AgriTech categories set out earlier.

- **Cost of AgriTech category and product** – the costs of purchasing the product- or asset-specific investments necessary to use the product. Such costs can be long-term investments in improving business models or can be considered sunk costs (incurred costs that cannot be recovered), as they are necessary to upgrade existing products. Costs include both input costs (e.g. R&D, cost of purchase) and output costs (e.g. affordability).
- **Complexity of AgriTech category and product –** the technological intensity of the product and practices to be adopted, and the embedded degree to which complex information and knowledge are transmitted between adopters and innovators. Relatively low-complexity products are more likely to replace routine low-skill tasks, such as selecting the right fertiliser and pesticides compared to unlike high-skill tasks such as using sensors and drones to perform precision agriculture. Complexity is further heightened when AgriTech products are created without integrating local and tacit knowledge into the process, for instance when apps for users such as farmers do not consider what farmers value or what matters to them, thereby reducing their agency in the process. This can lead to failure to efficiently codify and transmit knowledge of the benefits of AgriTech products to farmers, and the reverse: the omission of local, indigenous and tacit knowledge that is essential to the integration and functioning of AgriTech products. This can end up in adverse incorporation – that is, integration into areas where there are unequal power relations, leading to poor socioeconomic outcomes (Hickey, 2013).
- **Capabilities of users of AgriTech –** the level of skill required to use an AgriTech product. We categorise two broad types. *Production capabilities* refer to the skills necessary for the efficient operation of a farm/factory with new technologies. These skills include merging old and new technologies for production, harvesting, quality control, operation and maintenance and monitoring of productivity. *Linkage capabilities* refer to the skills needed to decode transmitted information from other organisations, allowing diffusion of technology (Staritz and Whitfield, 2019). Both capabilities can be gathered through education, experience, specialised training programmes, learning through imitation or on-the-job learning.

The adoption of each AgriTech product depends on a combination of its varied forms of the 3Cs. It is critical to note that different actors in a value chain adopt, use and diffuse AgriTech in various ways. For instance, it may be difficult for micro-enterprises and farmers to adopt AgriTech due to the high costs, complexity and capabilities required; while for a large enterprise it is likely to be less difficult, especially if they already have the capabilities in-house. Therefore, from the outset, we need to understand who uses AgriTech and the implications of this.

The characteristics will vary according to the user and the type of AgriTech. For instance, use of precision sprayers for biochemical fertilisers (type: ag biotechnology and biochemistry) will entail high costs as the equipment is expensive; moderate levels of complexity, because many farmers will need to learn how to use the new equipment; and a high level of capability as, although the technique of farming will not change considerably, the application procedure for biochemicals will, and this can involve learning to interface with IoT devices to ensure the sprayer sprays the right amount of fertiliser. Meanwhile, in using sensors (type: data-connected devices), farmers will need to invest more and the product can be highly complex, requiring a sophisticated set of skills. Table 2 shows how users with less agency (e.g. farmers, small cooperatives, women, micro-enterprises) experienced adoption of AgriTech products.

Table 2 Examples of user experiences of AgriTech in Kenya, Uganda and Rwanda

AgriTech category	AgriTech product examples	Cost of product	Complexity of product	Capabilities of users	Experiences of users
Data-connected agriculture	Android apps for market information (real-time price, weather updates)	Moderate: low to moderate costs for registering on apps and for the use of in-app services	Moderate: detailed information demonstrated to users on functioning of apps, with help of local champions	Moderate: requires learning to use smartphones and app functions	Users reported moderate technological skills required to use an app, and were often provided with support from 'village agents' or local champions who helped them navigate in-app services
Smart warehousing and logistics	Blockchains for traceability of products	High: expensive to use blockchains owing to high transactional costs but most blockchain services are not yet mainstreamed so users receive them at subsidised rates	High: complex procedures to register and open blockchain accounts, as well as simultaneously merging existing bank accounts with blockchains	High: difficult operation and learning of blockchains, as well as ensuring no mistakes, as impossible to reverse transactions	Users reported difficulty in learning and uptake, without constant support from firms deploying blockchains. Most blockchain products are currently heavily subsidised; without subsidies prices would be high
Farm robotics and automation and data-connected agriculture	Remote sensors for satellite imagery and land mapping	High: purchase of remote sensing equipment	High: difficult to install, operate and maintain remote sensors	High: production and linkage capabilities required to learn new technologies	Users reported low ability to understand how to use sensors and connected technologies
Ag biotechnology and biochemistry	Use of precision sprayers for biochem	High: purchase of new equipment	Moderate: using new types of sprayers	High: interface with several devices to ensure spray is precise	Low capability of farmers to use and maintain sprayers; inhibitive costs prevent uptake

Source: ODI key informant interviews (KIIs), April–July 2019 in Kenya, Uganda and Rwanda

3.3 Landscape of AgriTech in the EAC

AgriTech in Africa receives limited funding, owing to several constraints with regard to the business ecosystem (investment, doing business environment, financial systems), data infrastructure (digital payments, digital ID, digital literacy, digital policies), human capital and connectivity, cloud services and network access (BCG, 2018; Tsan et al., 2019). In terms of AgriTech related deals (these are bilateral or multilateral agreements struck between parties and funding from private equity, listed and unlisted companies, banks and other financial institutions) over $16.9 billion took place across the world in 2018 (AgFunder, 2018). Africa receives a very low volume of deals (in terms of bilateral or multilateral agreements struck between parties) and funding from various private, public and development financial institutions, of less than $100 million. The US dominates the global agri-food technology investment landscape with 567 deals struck worth $7.9 billion investments in 2018, a 23% jump on 2017 numbers, followed by China with 184 ($3.5 billion) and India with $2.4 billion, an impressive 280% increase year-on-year (AgFunder, 2018).

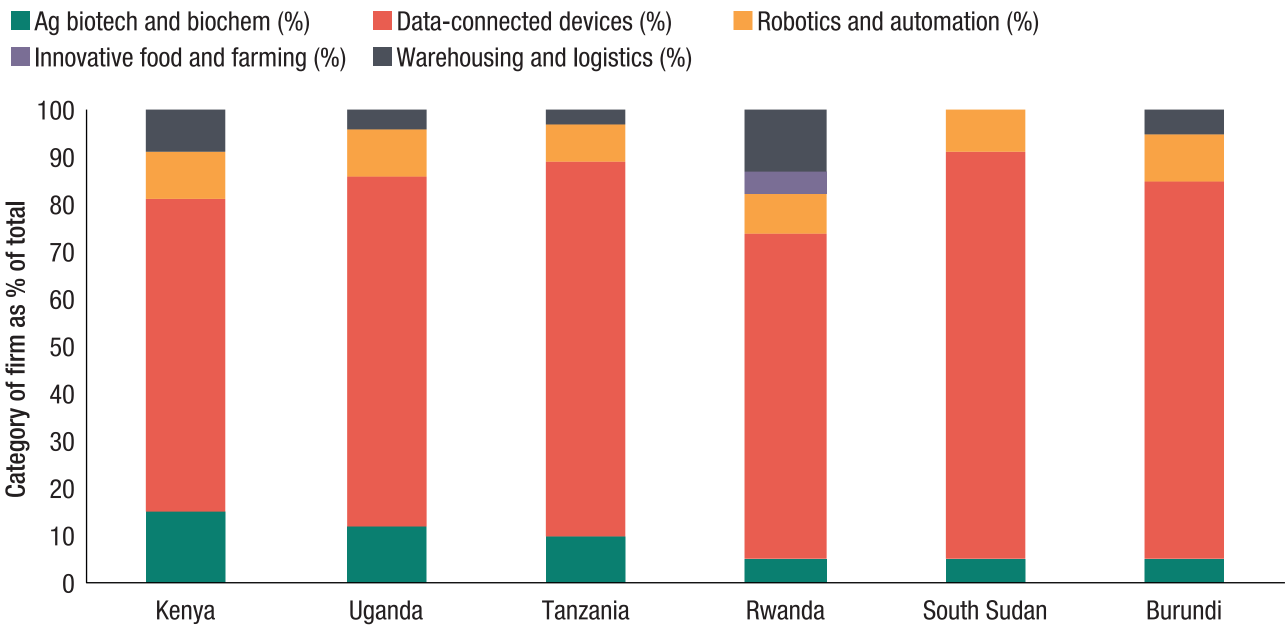
According to Briter Bridges 2018 AgTech Ventures map (Briter Bridges, 2018), Africa has seen substantial growth in AgriTech, reaching $20.4 million in investment. While there are significant divergences in figures for Africa, there is still clear evidence that these values are increasing. Both AgFunder and Briter Bridges data show that in 2018 data-connected agriculture, solar energy and drones are where most investment has occurred. Geographically, this is focused on East and South Africa and areas of West Africa.

The main AgriTech innovations currently adopted in developing countries are digital platforms, such as mobile and web apps, used to facilitate information, financial and commodity transaction processes along agricultural value chains (Koskinen et al., 2018; Ezeomah and Duncombe, 2019). Côte d'Ivoire, Ghana, Kenya, Nigeria, Senegal, South Africa, Uganda and Zimbabwe have been described as hotspots for digital-tech solutions (GSMA, 2018). There is also evidence of an expanding start-up ecosystem in these developing regions, made up of young innovators who are leveraging low-cost digital platforms, funding from international donors (including the EIF), and incubation activities to address agricultural value-chain issues in Africa. These digitally-enabled entrepreneurs are championing platform-based AgriTech initiatives that are creating disruptive ripple effects across developing country agricultural value chains (Boateng et al., 2017)

Through a novel dataset developed by ODI of 70 firms in 2018 in the EAC,[7] we flesh out the most prevalent types of AgriTech across the AgriTech categorisations.

Our research finds that, in the case of each country in the EAC, between 66% and 86% of firms fall within the data-connected devices category, with ag marketplaces (platforms) the most important, followed by ag biotech (mainly seeds and chemicals) purchased from Monsanto and precision agriculture (use of irrigation and spraying equipment). *This implies that, rather than more complex and R&D-demanding clusters of ag biosciences, robotics and automation, it is software, in terms of platforms, and data that take up the largest share of AgriTech within the EAC.* Most of the firms providing AgriTech products are micro and small enterprises, with some multinational companies (MNCs), international organisations and civil society organisations (see Annex 2 for types of firm). These firms are funded primarily through seed capital and series A, B, C funding from private capital (angel investors, private equity and foundations) and development finance institutions[8] to the tune of about $424 million over the past decade.

Figure 5 AgriTech categorisations 2017–2018



Source: Authors' calculation from ODI dataset

7 Data collected using secondary methods from Crunchbase, LinkedIn searches and key informant interviews. The total dataset consists of: Kenya = 32, Uganda = 14, Tanzania = 10, Rwanda = 6, South Sudan = 4, Burundi = 4.

8 As per the Organisation for Economic Co-Operation and Development (OECD), these are specialised development banks or subsidiaries set up to support private sector development in developing countries. They are usually majority-owned by national governments and source their capital from national or international development funds or benefit from government guarantees.

3.3.1 Agricultural biotechnology and biochemistry

Agricultural biotechnology can assist breeders in improving yields and quality of crops. Through its breeding programme, the International Institute of Tropical Agriculture has successfully developed varieties of cassava resistant to endemic diseases such as African cassava mosaic virus, cassava bacterial blight and cassava anthracnose, and varieties resistant to pests such as mealy bug and green mite. The breeding programme also targets the improvement of cassava quality by developing modified varieties lower in cyanide. In another example, bioinformatics and genome science is gradually gaining ground in East Africa (Karikari et al., 2015). For instance sorghum, a nutrient-rich crop, was the first indigenous crop in Africa to have its genome completely sequenced, leading to significant genetic improvement in sorghum and other cereal crops to enhance crop yield, agricultural productivity and food security (ibid.). Over the past decade, research organisations such as the African Society for Bioinformatics and Computational Biology ASBCB) and the Alliance for Accelerated Crop Improvement in Africa (ACACIA) have emerged to develop infrastructure and competence within bioinformatics and computational biology. Several researchers within Kenya have been trained and form part of the larger Biosciences Eastern and Central AfricaBiosciences Eastern and Central Africa, a New Partnership for a New Partnership for African Development initiative that supports the expansion of bioinformatics training and research efforts in East and Central Africa. These research consortia have gone a long way in promoting bio-logics in universities such as KARLO and Makerere in Kenya and Uganda respectively.

3.3.2 Smart warehousing and logistic technologies

RFID: In Namibia, the Namibian Livestock Identification and Traceability System adopts RFID and QR codes to improve the traceability of products along the beef value chain. This system has been used to track animal movement, monitor animal health, control animal disease and manage animal nutrition. The adoption of a traceability system using RFID technology has helped connect Namibia to global beef value chains, improving the livelihoods of Namibian pastoralists (Prinsloo and de Villiers, 2017).

Blockchains for quality: Coffee, the second most traded commodity in the world, is a $100 billion market worldwide. Supply chain technology provider bext360 partnered with Great Lakes Coffee, a Uganda-based coffee exporter, and Coda Coffee, a Denver-based coffee roaster, to launch a pilot to trace coffee from Uganda to Denver, Colorado, in the US (Knapp, 2018). Farmers' cooperatives deposit coffee cherries for analysis at washing stations, where they are also paid for their harvest. From this collection point, the product will be tracked and analysed all the way to Coda Coffee in Denver, where the coffee will be roasted and available for purchase. Bext360 uses machine learning, AI and IoT to evaluate coffee cherries and beans and grade cherry and bean quality. The machine employs blockchain technology from Stellar.org to track data about the coffee's origin and quality and allows for digital payments to farmers via a mobile app. The bext360 platform enables all stakeholders – farmers, roasters and consumers – to access data across the entirety of the supply chain. This enables complete analysis of the supply chain to identify supply chain efficiencies, as well as allowing more compensation to farmers who produce higher-quality coffee cherries (Communicaffe International, 2017).

Supply chain management: iProcure is the largest agricultural supply chain platform in rural Africa (iProcure, n.d.). In addition to complete procurement and last-mile distribution services, the Kenyan company provides business intelligence and data-driven stock management across the supply chains.

Smart warehousing: Use of QR codes and wearables optimises productivity by reducing search times and increases operating savings by cutting employee travel times, which absorb a significant portion of workers' shifts. Companies such as Ryder (Hitch, 2019) based in the US are rolling out wearable glasses to reduce time taken to pack products, and drones within factories to can pallets and locations, versus a manual scan. DHL has introduced flexible smart warehouses in South Africa with ambient temperature sensors.

3.3.3 Data-connected devices

In **Kenya**, Twiga Foods is a platform that connects fresh fruit farmers with road-side vendors in urban and peri-urban areas (Twiga, n.d.). The platform sources fresh fruits and vegetables (FFVs) from rural farmers and delivers these to urban and peri-urban vendors who have registered on the platform. This has helped reduce the number of intermediaries between rural farmers and vendors on the FFV value chain; reduced transaction costs incurred by both farmers and vendors in coordinating sales; and also ensured that quality FFVs are able to reach the final consumers in good time (GSMA, 2018). By on-boarding farmers and vendors on its platform, Twiga is transforming interactions between farmers and vendors by improving trust and transiency in FFV value chains in Kenya.

Additionally, in Kenya, AgroCare has developed a mobile app that provides tailored fertiliser recommendations to farmers using soil data collected using a portable scanner. This ensures farmers apply fertilisers more economically, focusing on problem areas, thereby reducing waste and increasing outputs (Price, 2018). AgroCare uses portable soil sensors, together with big data and analytics, to provide precise analysis of soil requirements.

Kenya is a hotspot for agricultural apps. Organisations such as Precision Agriculture for Development (PAD), a global non-governmental organisation (NGO), focus on integrating greater precision into digital smallholder advisory extensions with the support of remote sensing data, other data such as weather patterns and soil types, behavioural science techniques (for solution design and testing) and rigorous evaluations (i.e. randomised controlled trials) of resulting advisory outcomes. Satellite imagery analytics are the cornerstone of PAD's precision advisory solutions in Africa. The information is frequently transmitted to farmers by SMS, thereby allowing for greater penetration.

Tulaa is an Android-based app that operates through a 'village agent model', whereby the agent controls the app and disseminates information to farmers as well as loans into their digital wallet. Tulaa offers digital credit in Kenya, which is integrated into a digital end-to-end market linkage model, connecting farmers to buyers; and digital loans from Apollo Agriculture. Together, these are bundled into a digital advisory product for farmers. Many of these players rely on digitally enabled credit-scoring algorithms to suss out farmer creditworthiness. Tulaa relies on commissions from farmer market linkages and related transactions (Tsan et al., 2019; KIIs, 2019).

In **Uganda**, the market-led, user-owned ICT4Ag-enabled Information Service is a satellite data-enabled extension advisory service that uses satellite data to provide agronomic information and weather forecasting to help farmers make informed farm management decisions (Price, 2018). The service uses ICTs to address the current agricultural information gap in Uganda.

Blockchains for ag-insurance: Key players on the agricultural micro-insurance value chain, Agrics (an East African social enterprise serving 30,000 farmers in Kenya, Tanzania and Uganda with quality agricultural products and services on credit) and EARS (Environmental Analysis and Remote Sensing, a Dutch-based remote sensing company with 10 years of experience in designing and implementing drought index insurance solutions in Africa) started out in early 2017 to research intensively the potential of developing a low-cost drought index insurance product supported by blockchain technology. With this began a partnership with COIN22, a financial technology company providing a blockchain-based mobile wallet platform, and its agent Dodore Kenya, which specialises in implementing mobile financial services in East Africa, and the FAO to develop first a drought index savings product that helps farmers grow into the concept of insurance. This began in 2018, through the Financial and Agricultural Risk Management for Smallholders scheme (Sylvester, 2019).

The FARMS concept is enabled by a blockchain-based virtual currency platform integrated with remote sensing (satellite) data and mobile money solutions, which ensures transparent secure transactions and 'earmarking' of funds, automated payment and information dashboards. Farmers set aside money by buying virtual currency 'drought coins' or 'drought vouchers' (a voucher being a concept that many are familiar with) that are kept in their personal COIN22 mobile wallet account. When farmers want to withdraw funds, they redeem their drought coins/vouchers. The value of the coins mimic the local fiat currency; for example, 5,000 Kenyan shillings represent 5,000 coins. All transactions are communicated to the farmer, and participants can check their balance at any given moment, through a universal SMS. The actual money flows into a trusted bank account (risk pool), and through full systems integration all transactions are in real time.

3.3.4 Robotics, automation and AI

Remote sensing through drones in Tanzania: The National Food Security Division in the Ministry of Agriculture, Livestock and Fisheries, in collaboration with Sokoine University of Agriculture and the University of Maryland (US), began implementing a project aimed at transforming the agriculture sector through a technological breakthrough based on crop monitoring in 2018. The project, Spurring a Transformation for Agriculture through Remote Sensing, adapts and develops advanced remote-sensing techniques and applications to monitor crop conditions in collaboration with end users (GIS Resources, 2016). The main objective of the national food security bulletin was to update decision-makers and the public on crop growth stages, conditions, prices and post-harvest to help them in planning and management. The bulletin, disbursed to farmers, carries information on major crops such as cassava, beans, paddy and maize, account for 40% of the national food basket.

In Kenya, ThirdEye is setting up a **network of flying sensor operators** equipped with tools to analyse the obtained imagery. The main aim is to support irrigation and reduce the dependence on water resources. In 2018, ThirdEye formed part of the Smart Water for Agriculture programme implemented by SNV (a not-for-profit international development organisation), serving at least 2,000 smallholder farmers. Operations took place in Meru and Nakuru, where training was performed on flying sensor use, technical skills, safety and protocols and imagery processing. The flying sensors use a high spatial resolution, which picks up precise changes in plant leaf colours to ascertain when plants require watering. Furthermore, the combination of a flying platform and a camera provides visual location of areas that need immediate support.

Automation and AI: Automated mobile survey technology and spatial modelling of viral cassava diseases in Uganda has been developed by Makerere University in conjunction with Pulse labs Uganda. The smartphone survey system is largely built on ODK Collect and Google App Engine, with significant customised coding for automated diagnosis and mapping. Fieldworkers can capture images and immediately upload them, which in turn is put into AI machine learning techniques to develop a visual diagnosis, which is sent back to the fieldworkers. This app has been functioning since 2017, and has around 85% accuracy with whitefly counts, Brown Streak Virus and Mosaic Virus in cassava plants (KIIs, 2019). The Institute for Grape and Wine Sciences is working on a robot in South Africa for data-gathering purposes in vineyards: a sensory facility where expert tasting panels can compare the aroma and mouth feel of various wines (Duvenage, 2017).

3.3.5 Innovative food and farming

The best-known alternative to current farming systems is indoor farming: growing produce in high-tech greenhouses and automated vertical farms. This includes aquaponics and hydroponics along with production facilities for new living ingredients such as insects and algae. Fresh Direct Nigeria brings fresh premium organic produce closer to the market with its container farm technology. Using hydroponics and vertical farming within a shipping container, the company is able to grow directly in urban areas. Using fly larvae fed on existing organic waste, AgriProtein from South Africa has developed and tested a new large-scale and sustainable source of natural protein (AgriProtein, n.d.; Belmaachi, 2018).

3.4 AgriTech in value chains: changing chain operations

AgriTech can be adopted at two different scales within a value chain: (1) specifically targeted to one node of the value chain, such as use of seeds; or (2) connecting multiple nodes of the value chain simultaneously, such as in ag platforms (backward and forward linkages). For instance, biotech and nanotechnology are often used in backward links or upstream in the chain, along with use of farmers' apps, and automation and robotics, especially in large farms in developed countries. Smart warehousing and logistic tech such as blockchains for traceability and data for fleet optimisation are used during the transport stage, followed by e-commerce at the retailer end of the chain, as Figure 6 shows.

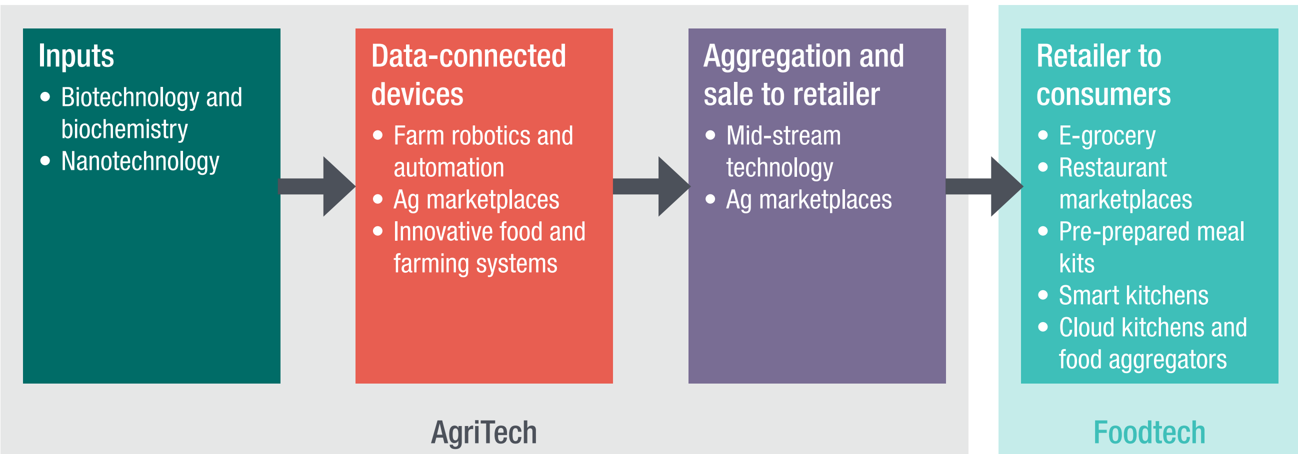
In developing regions where digital transformation is at a relatively lower level, there is evidence that innovators who are using digital platforms to develop low-cost AgriTech solutions have replaced traditional ways that agriculture value chains have functioned by causing disintermediation (which means reducing the number of brokers and middle men) and increasing the transparency of financial exchanges, be this through working capital loans, insurance or financial transactions through wallets and blockchains. In the production node for instance, VASs, such as market information (price, weather) and extension services (good agricultural practices, pest and disease control), the use of apps that connect farmers to buyers (processors, wholesalers, retailers) has affected overall transaction costs (Foster et al., 2018).[9]

3.4.1 Mapping actors in AgriTech value chains

There are two key types of actor in value chains: vertical and horizontal actors. Vertical actors are those involved in different commercial activities of the value chain, from production to retail. These actors are involved in creation of the ag-product and its marketing and retail. These include actors at the:

1. **Stage of production:** (1) product input providers, including MNCs supplying seeds, chemicals and fertilisers; (2) technology providers, providing data capturing devices such as sensors, robots and drones; (3) start-ups firms, which provide innovative solutions for value-chain efficiency and integration; and (4) farmers and farmer cooperatives

Figure 6 AgriTech in value chains



Source: Authors

9 Different research indicate varied implications: while Foster et al. (2018) suggest that inequalities are reproduced and rents are accumulated by larger players in the value chains, others (e.g. Tsan et al., 2019) indicate reduction in overall costs of production and efficiency.

2. **Intermediary stage:** (1) brokers, conventionally individual middlemen who purchase from farmers at a commission; they can also be large MNCs such as Cargill and Olam, which aggregate and process products bought; a third variant comprises emerging ag platform firms that connect and often guarantee farmers products when selling onto retailers; (2) logistics companies; (3) associations; (4) processors; (5) data aggregators and analytics providers, which summarise and standardise data across data sources and search for patterns in the data through algorithms and decision support applications; and (6) firms providing midstream technologies such as blockchains and logistics
3. **Retail and consumer stage:** (1) the retail private sector – buyers such as supermarkets, fast moving consumer good companies and convenience stores; (2) wholesalers, who typically buy goods direct from the producer in large quantities, often for resale; (3) physical restaurants and cloud kitchens (takeaway outlets that provide no dine-in facility; they function as a production unit with a space for he preparation of food, which can be ordered online); and (4) end consumers, who are individual buyers purchasing through retailers.

Horizontal actors are actors not directly involved in production activities but who play an important role in facilitating the functioning of the value chain (Stein and Barron, 2017).

1. **Public actors.** These include national and sub-national governments and regional governments like the EAC. For instance, the Kenyan government, through investment in digital infrastructure such as the East African Marine System undersea fibre cable and the National Optic Fibre Backbone Infrastructure, has supported the development of digital innovations across all economic sectors including agriculture, as well as robust policy and legal frameworks to govern the use of ICTs in the country (Waema and Ndung'u, 2013).
2. **Supra-national unions** such as the African Union have pushed for digital ag investment as part of the Comprehensive African Agricultural Development Programme Agenda 2063, especially to support women and youth in agriculture.
3. **Intergovernmental organisations** such as the UN, the World Trade Organization (WTO) and the OECD. For instance, the WTO in its recent symposium on the role of trade in the global agri-food system discussed the tariff and non-tariff measures that need to be applied to global agri-food systems when encountering poor ICT facilities, climate stress and increased uncertainty (WTO, 2019); and a refocus on domestic support and how domestic policies can be tailored to allow limited public funds to be used for investments in sustainability and resilience while minimizing distortions to production and trade.
4. **Social actors –** civil society organisations (e.g. CGIAR, CARE) and NGOs, both local and international. For instance, TechnoServe, a CSO, is supporting development (along with the World Bank) of a warehouse receipt system called AgriManagr, which manages recording of the weighing, grading and receipting of produce collected from each farmer at collection points while simultaneously serving as a proxy for a farmer's creditworthiness.
5. **Associations**, which can be local, such as the Eastern Africa Farmers Federation, which developed the e-Granary app to match buyers and sellers; or international, such as GSMA (body representing interests of mobile operators worldwide), which has set up an ecosystem accelerator innovation fund for 35 AgriTech start-ups in East Africa. Additionally, there are long-standing industry associations, such as the Kenya Association of Manufacturers, which has included the digital economy as a key pillar in the manufacturing priority agenda for 2019 and performs policy advocacy for agro-processing and manufacturing firms in Kenya.
6. **International financial actors, donors** (e.g. the World Bank, the United Kingdom Department for International Development, FAO, the Centre for Agriculture and Bioscience International, the International Fund for Agricultural Development) and *foundations* (e.g. Bill and Melinda Gates, Syngenta, Microsoft, Google). Donor funding in this region is also applied in the form of

incubation spaces and business development training, which helps shape viable AgriTech ideas into scalable businesses. The World Bank Group is also partnering with national, regional and international organisations over the next three years to establish Africa's first AgriTech incubator in Kenya. As part of the One Million Farmer Platform, this incubator will support the diffusion of AgriTech innovations by connecting over a million Kenyan farmers to a digital platform – for market access, production information and financial services (Tsan et al., 2019). Meanwhile, the US Agency for International Development (USAID) and the Swedish International Development Cooperation Agency (Sida) are working in partnership with the Association for Strengthening Agricultural Research in Eastern and Central Africa to develop the Regional Agricultural Trade Intelligence Network in Kenya. Another example is the Syngenta Foundation is working in partnership with Safaricom to develop a digital payment initiative.

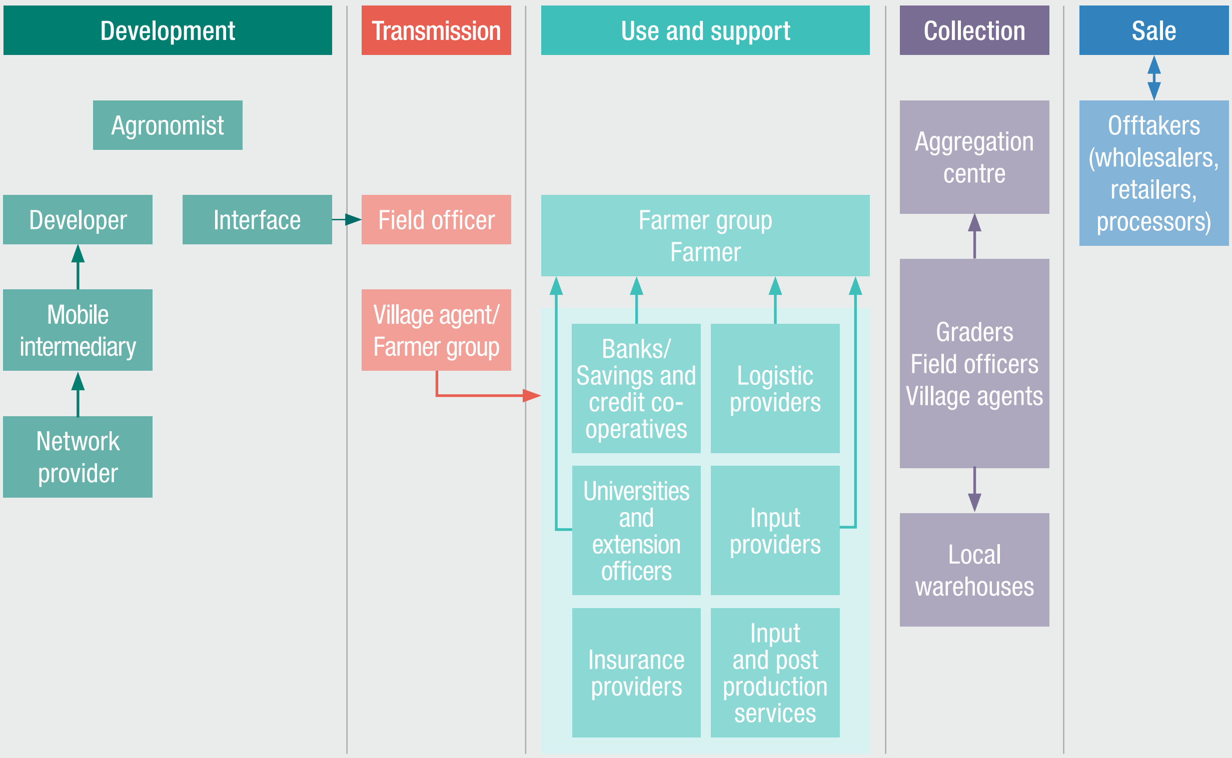
7. **Other private financial investors,** such as venture capitalists, angel investors, private equity and debt financing. For instance, in Kenya, Twiga Foods, an AgriTech start-up, is funded by venture capitalists such as TLcom Capital LLP, the Global Agriculture & Food Security Program and Omidyar Network. WeFarm is funded by True Ventures, Accelerated Digital and LocalGlobe (Partech, 2018).
8. **Local financial institutions (private and public) and insurance companies**. The most common Tier 3 financial institutions are microfinance institutions that are allowed to accept deposits from customers but only in the form of savings accounts. These banks are also known as microfinance deposit-taking Institutions. In Uganda, these include FINCA Uganda and Pride Microfinance; in Kenya, 21 Tier 3 banks control 8.4% of the Kenyan market, including Paramount Universal, ABC, Credit Bank, Guardian, SBM Bank, and Jamii Bora Bank of Kenya. These banks can give smaller loans and have a greater number of subordinated issues, undisclosed reserves and general loss reserves than conventional banks. Insurance providers are classified as Tier 4 financial institutions. ACRE Africa along with the Syngenta Foundation in Kenya, Tanzania and Rwanda is one of the largest agriculture insurance service providers through its Kilimo Salama initiative, started in 2009. This project has reached about 1,700,000 farmers in Kenya, Tanzania and Rwanda, who are insured over $181 million against a variety of weather risks underwritten by UAP Insurance Kenya, CIC Insurance Group, APA Insurance, Heritage Insurance, UAP Insurance Tanzania and SORAS Insurance Rwanda (ACRE Africa, n.d.).
9. **Education actors**. Universities, technical and vocational education and training organisations and national agriculture research centres are crucial actors in facilitating human capital development and as spaces for incubating talent. For instance, according to Tsan et al. (2019), low levels of digital literacy and comfort among farmers and agricultural agents constrain demand, adoption and use of offerings. In 2014, the Technical Centre for Agricultural and Rural Cooperation ACP-EU (CTA) collaborated with Klab and others on the Rwanda National ICT For Agriculture Hackathon. Carnegie Melon, Andela University and African Leadership University have talent centres in Rwanda that build needed local skills. Annex 2 provides a list of some of the key actors in the EAC.

Overall, this suggests there can be a mix of institutional configurations, depending on the categorisation of AgriTech, to support creation, adoption and diffusion. Vertical and horizontal actors need strong and cohesive ties, both between and within themselves. These ties range from *cohesive and cooperative*, where all actors have shared ultimate goals, to *fragmented*, wherein not all actors are on board, causing resistance and slowing down the process of AgriTech adoption and diffusion. There are also situations of *institutional voids*, which create a vacuum – suggesting *no linkages exist*. These create significantly negative effects on AgriTech growth opportunities. The box below provides an example of a popular app in Kenya called e-Granary, which clearly highlights the multiple horizontal and vertical actors that are required to facilitate operation of the app.

Box 1 e-Granary in Kenya

The Eastern Africa Farmers Federation is running the e-Granary mobile platform to increase access to market information and e-extension services for farmers to mitigate the lack of access to conventional extension services in Kenya. The project meets the needs of farmers by using mobile phones to increase their access to real-time market information, which helps inform food production and trade within the region. The e-Granary platform enables farmers to decide when, where and at what price to sell their products. This information helps them make more informed production and marketing decisions. The project began in 2018 and currently has 250,000 registered farmers. It sends targeted voice messages to registered farmers based on location and crop. The most common crops are maize and sorghum in Meru and Trans-Nzoia counties in Kenya. The vertical and horizontal actors and their relationships are presented below.

Figure 7 e-Granary networks



Source: Authors

The network is divided into five stages: development, transmission, users and support, collection and sale. The first stage consists of relationships between Safaricom as the key mobile operator, mobile intermediaries who negotiate unstructured supplementary service data code rates, e-Granary platform developers and agronomists, to provide key information to input into the platform. The transmission stage involves field officers hired by e-Granary and village agents (proactive individuals who are appointed as champions) who train and disburse the product to cooperatives, who are the main users. The various services provided by e-Granary include extension (through universities), working capital at lower interest rates (through savings and credit cooperatives), transportation (through local motorcycles) and partnerships with several input providers (agrochemicals, fertilisers, seeds and saplings), which provide farmers with inputs at a discount when bought as a package. e-Granary collects all the harvested maize in its aggregation centre, where field officers weigh and grade the product before sending it to an off-taker (buyer).

4 AgriTech disruption: definition and typology

The key question within the AgriTech literature is whether such technologies have the potential to be disruptive. However, there are few studies explaining what disruption is or who may be disrupted, how value-chain actors are disrupted, the extent to which the potential disruption experienced varies, or the contexts conducive to disruption. In this section, we attempt to conceptually define what disruption means and provide a 2*2 matrix to describe four key disruption types that can be applied across AgriTech categories and products and across different actors in a value chain.

International business describes disruption as an event that displaces incumbent firms, creates a new market and shifts consumer demand to the new innovation within an established market. Christensen's innovation disruption theory posits two types of disruption based on changes in market behaviour: new market disruptions that create new consumer demand for the disruptive innovation; and low-end innovation that provides cheaper alternatives to incumbent products (Christensen and Raynor, 2003). Disruption has also been conceptualised from an innovation diffusion standpoint, mapping out the pathway through which an innovation is adopted in an existing market. Building on Roger's (1995) innovation diffusion theory, Schmidt and Druhel (2015) divide the market into high- and low-end consumers based on their level of adoption of incumbent innovation. They argue that an innovation is disruptive if it diffuses through a 'low-end encroachment' pathway starting from consumers with the lowest adoption rate for existing innovation (those with less willingness to pay) to high-demand consumers for the old technology.

Other scholars (Abernathy and James, 1978; Anderson and Tushman, 1990; Rogers, 1995; Dahlin and Behrens, 2005; Nagy et al., 2016) have also argued that disruptive innovations possess common characteristics that qualify them as disruptive. Nagy et al. (2016) draw on these debates to highlight three innovation characteristics that result in disruption. An innovation is disruptive if it (1) provides new functionalities that enable consumers to perform new tasks, or old tasks more efficiently – radical functionality; (2) uses low-cost inputs and process to produce existing technologies – discontinuous technicality; and (3) adopts an innovation ownership model that influences the price and consumers' expectation of incumbent innovations – changes the model of innovation ownership. The authors also introduce the concept of relative disruption, arguing that an innovation could be disruptive to one group but sustaining or incremental to another. In summary, disruption is brought about by new innovations that address existing problems more efficiently, at a lower cost (frugal) and more accessibly to groups that were underserved by previous innovation, thereby creating a new market for the innovation (Christensen, 1997; Schmidt and Druhel, 2015).

Disruption has been theorised as a necessary phenomenon for economic growth (Schuelke-Leech, 2017). Innovations such as ICTs, which have been responsible for the 'digital revolution', have catalysed global economic transformation processes, leading to radical changes – beyond the communication industry (Liversidge, 2015). Joseph Schumpeter pioneered the concept of creative destruction, which posited a causal relationship between what can be understood as disruptive innovation and economic development. He argued that the replacement of existing technology with new innovation caused a 'creative destruction' that drives economic development, implying that countries that do not innovate tend to remain stagnant (Schumpter, 1942). AgriTech such as drones, precision farming systems and IoT have already disrupted developed countries' agricultural systems such that agricultural production depends completely on these technologies (Oliver et al., 2010).

The ubiquity and affordability of ICT infrastructures, especially in developing regions, have provided a cost-effective means for sharing information; providing financial services to the underserved; and extending agricultural technologies to rural communities (Aker and Mbiti, 2010; Deichmann et al., 2016). It has been theorised that ICTs have the potential to transform traditional industries, such as agriculture, into digitalised industries, leading to disruptive impacts within agriculture with extended ripple effects across rural economies. The disruptive potential of ICTs has been attributed to (1) increasing specialisation and the drive for improved efficiency; (2) digitalisation of products and processes that were previously not digitalised; (3) embedding software into products and services; (4) IoT – the communication between hardware and software; and (5) the ubiquity of digital technologies, especially as a result of wireless internet connection and mobile devices (Yoo et al., 2012; Tiwana, 2013).

Digital platforms have been described as disruptive innovations because of their propensity to transform systems in which they are introduced (Kazan et al., 2014). However, it is important to note that disruption is not a linear process, and can affect different vertical and horizontal actors in a value chain differently. Thus, understanding disruption from an agricultural development perspective, it is imperative to understand first what disruptive innovation is; second, to whom it is disruptive; and third how it is disruptive. This is especially because agricultural value chains in the EAC are made up of large numbers of farmers who are less able to respond strategically to changes in their business environment. As such, it is important to fully understand the implications of mainstreaming AgriTech innovations into agricultural value chains so that the benefits can be harnessed while the negative aspects can be mitigated.

Disruption can take two forms:

1. Substituting existing products, processes and business models: AgriTech can be transformational, first, if it involves displacement of incumbent practices that have been existing in a sector or value chain; second, when there is a complete overhaul or radical change in business operation models or the modus operandi of actors; third, when it creates new markets for the poor, such as those created by digital platforms; and fourth, it enables behavioural change through changing cognitive rationalities, which finally leads to changing the underlying norms and culture of the society.
2. Complementing existing products, processes and business models: this occurs when AgriTech supplements existing products, processes and business models. Therefore, it may lead only to alternations or modification in the modus operandi and partial changes to production practices. In this case, behavioural change may occur, but it does not change the underlying norms and cultures of society.

Thus, a disruption scale exists that ranges from high AgriTech disruption potential under substituting to lower potential under complementing, as Figure 8 shows.

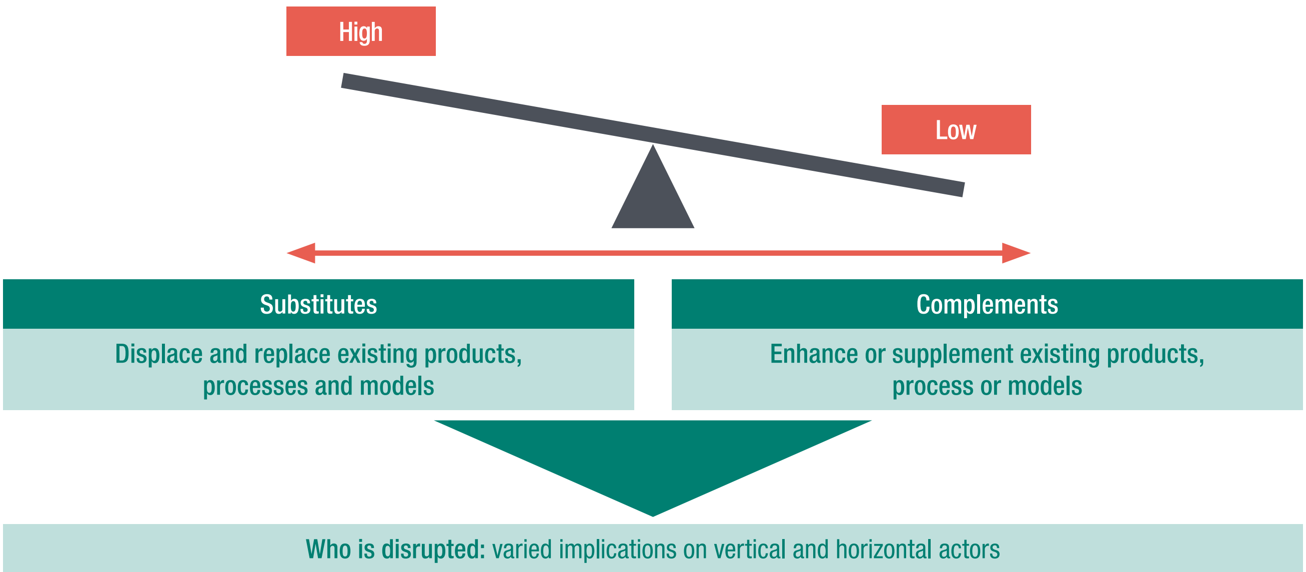
4.1 AgriTech disruption in value chains: a typology

To develop a disruption typology for AgriTech, we use the characteristics of AgriTech categorisations from chapter 3 – the 3Cs, or *cost* (i.e. the cost of purchasing the product or asset-specific investments that need to be made in order to use it); *complexity* (related to the technology intensity of the product and practices to be adopted); and *user capabilities* (the level of skill required to use the product) – combined with the sliding scale of AgriTech disruption (explained above), to create a matrix of AgriTech disruption in value chains. This provides a heuristic understanding of the typologies of AgriTech disruption that can occur.

In Figure 9, the y axis denotes the 3Cs of AgriTech and the x axis the disruption scale of complementary versus substituting potential. This is further divided into four quadrants, which incorporate four different combinations of the 3Cs and disruption scale to create types of disruption technology. This heuristic framework can facilitate inserting various types of AgriTech into each quadrant. This will allow policy-makers to classify the disruptive potential of a technology.

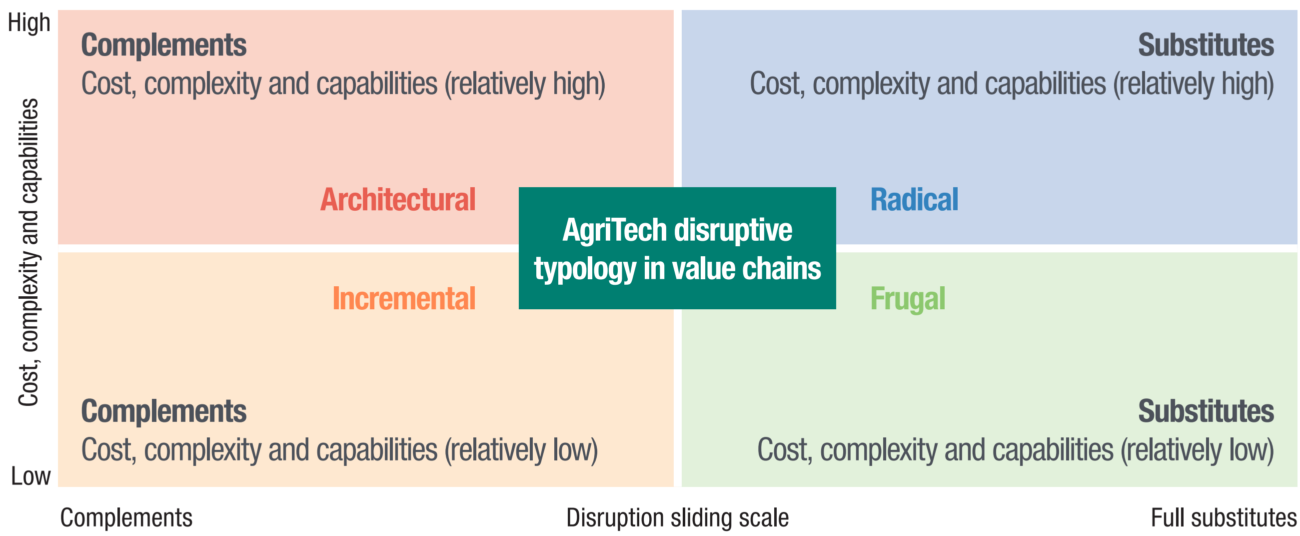
Quadrant 1: Radical AgriTech. This occurs when products are substitutes and the 3Cs are high. It takes place when products, processes and models are giving birth to new industries (or swallowing existing ones), involves adopting revolutionary technology and changes behaviour and societal norms. These newer technologies are often more expensive, have fewer features and are harder to use. It is only after a few iterations that the newer tech surpasses the old and disrupts all existing firms. By then, it may be too late for established companies to compete quickly with the newer technology.

Figure 8 Sliding scale of disruption



Source: Authors

Figure 9 AgriTech disruptive typology in value chains



Source: Authors' construction

Quadrant 2: Architectural AgriTech is often seen as developing complementary products/processes or modifying existing forms of AgriTech in specific sectors. This new AgriTech can be interoperable but at a high cost, enduring high complexity and requiring relatively high capabilities.

Quadrant 3: Incremental AgriTech is the most common form, whereby products and processes are tweaked, improved and complemented by related products and processes, thereby using existing technology while increasing value to the user within an existing value chain/sector. Examples include adding new features to existing products or services, or even removing features (value through simplification). This process sharpens or complements existing technology while keeping costs and complexity low.

Quadrant 4: Frugal AgriTech. This involves a substitution – that is, discovering new business models, reconfiguring value chains and redesigning products to serve users who face extreme affordability constraints, in a scalable and sustainable manner. In essence, such innovation simplifies the product components and manufacturing processes into basic elements, in order to redesign both the product and the processes to become more efficient and cost effective. It involves either overcoming or tapping institutional voids and resource constraints to create more inclusive markets (Bhatti, 2016). Unlike top-down innovation, where the target market comprises actors with the greatest purchasing power, frugal innovation as practised in emerging markets targets the bottom and then makes its way up to other levels to benefit all users. The dynamics of economies of substitution and frugal innovation create an intertemporal substitution of components and a process of modularity in the design of high-performance products (Sammut-Bonnici and Parouris, 2013).

This shows that disruption can occur through different processes and affect adopters differently. Table 3 provides examples of disruption types, using the AgriTech categorisation discussed in chapter 3. We use data collected from KIIs in Kenya, Uganda and Rwanda in 2019 in columns 3 and 4 of Table 3 to examine the disruptive potential for East Africa (especially in Kenya and Uganda) experience by virtue of these products.

4.2 Complementary factors that can affect the extent of AgriTech disruption: the enabling environment

To comprehend the full effects of possible disruption to users of AgriTech, it is necessary to unpack the broader enabling environment which facilitates positive outcomes of disruption. There are two sets of enablers: *top-down,* that aim to expand the environment to create and uptake AgriTech; these include (1) ICT (network connectivity, clouds, devices); (2) digital enablers (digital payments, online banking, data and digital policies); (3) business ecosystem (finance access, doing business environment); and (4) human capital (education and technical and vocational education training policies); and *bottom-up,* which target the users/adopters of AgriTech; these include (1) land rights; (2) cooperative acts for group formation; and (3) freedom of association and food security acts (Annex 2 contains a list of different data and agriculture policies in the EAC).

Lack of provision within the top-down and bottom-up enabling environment leads to a growing ag-digital divide. This means there exists a persistent digital divide between less developed countries (like those in East Africa) and their counterparts (developed countries) both in access to and use of technologies, which in turn affects their comparative advantage. For instance, as the global agriculture sector becomes more automated, farmers in developing economies who are able to invest in digitalisation are better placed to meet rising international standards, while other farmers with lower access to digital technologies face an increased threat of exclusion from the value chain.

4.2.1 Complementary factors for AgriTech disruption: top-down enablers

Connectivity and digital enablers: Although it is difficult to find sector-specific data on digital readiness, we compare EAC countries over a range of indicators that can help measure top-down digital enablers at the country level in the EAC. AgriTech enterprises rely on the reach, capacity and quality of connectivity infrastructure. In terms of basic ICT infrastructure (internet and broadband penetration), it has been observed that over 40% of Kenyans are internet users, with internet penetration in Rwanda and Uganda

Table 3 Examples of AgriTech disruption in Kenya and Uganda

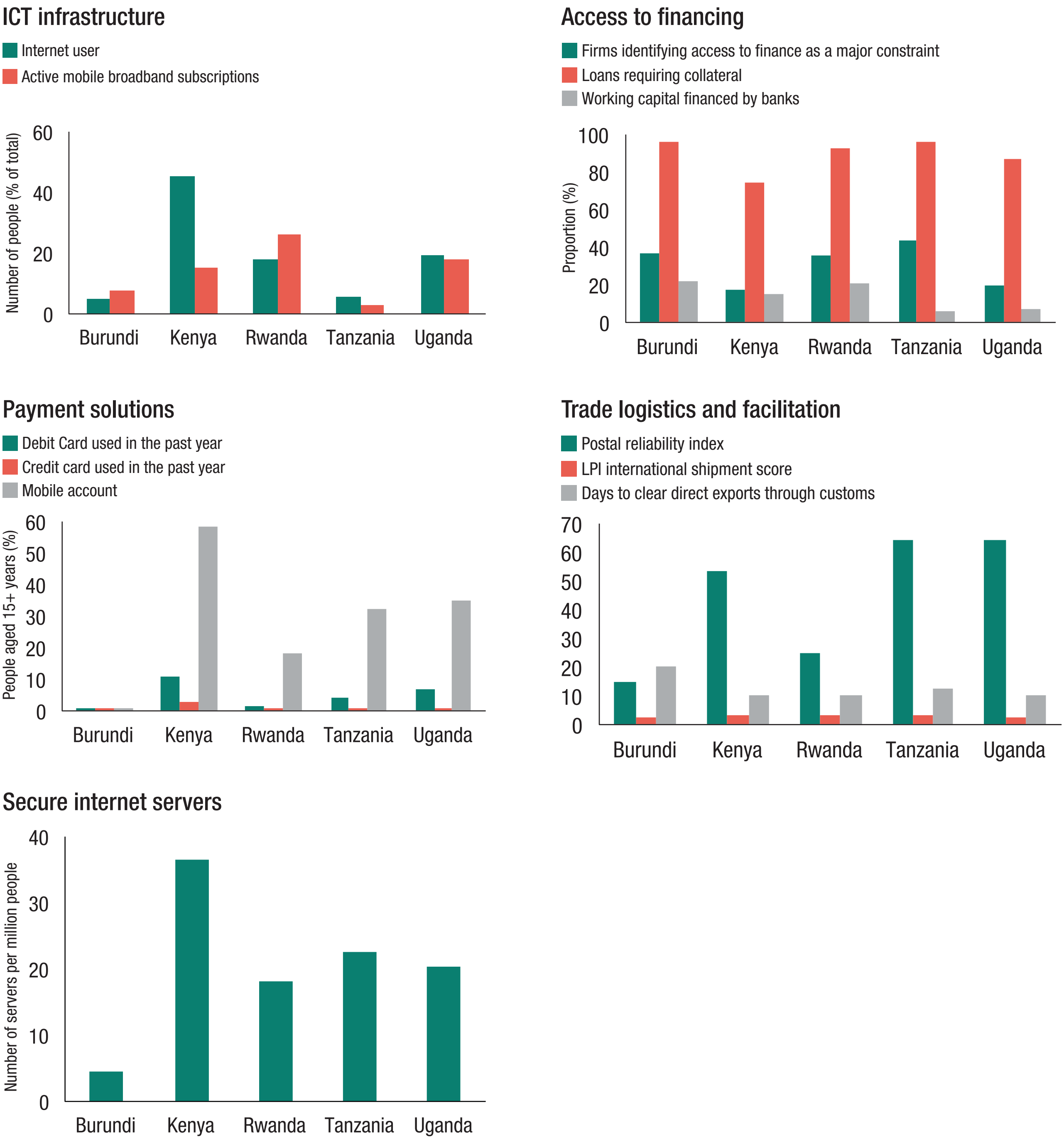
Disruption type	AgriTech category	East African user experience	Outcomes
Radical (Substitutes, with high cost, complexity and capabilities required)	Farm robotics and automation: Farm robotics through driverless farm tractors (e.g. Hello Tractor IBM); blockchains (e.g. Twiga Foods)	About 85% of users reported difficulty* in uptake but were optimistic about the possible increase in productivity and reduced transaction costs involved, especially with regard to gaining financial capital for production through Twiga's platform and receiving guarantees of finding buyers. *lack of financial capital and capabilities	Very disruptive, changing processes of production, and possibly influencing user behaviours, community-level behaviour and social norms, as these experiences are major shifts away from business-as-usual practices.
Architectural (Complements, with high cost, complexity and capabilities required)	Data-connected agriculture: Remote sensing projects: Spurring Transformation for Agriculture through Remote Sensing in Kenya; and Makerere's AI lab-driven automated visual diagnostics	Approximately 70% of users interviewed claimed an improvement in productivity from real-time information on land mapping, irrigation needs and disease control.	These products complement processes of production and sale, by enhancing them and allowing for capture of more value-addition potential by reducing transaction costs.
Incremental (Complements, with low cost, complexity and capabilities required)	Data-connected agriculture: Vegetable Oil Development Project with SAP, International Fund for Agricultural Development and Ministry of Agriculture in Uganda	Over 2,000 farmers are part of a vertically integrated chain selling palm oil to Bidco (an East African conglomerate). Working through the Kalangala Oil Palm Growers Trust, VODP engaged SAP Rural Sourcing Management software. This digitally records information on producers, farms and communities at every level of the value chain. This provides visibility and allows parties to easily and quickly communicate. The solution is cloud-based, which delivers real cost savings according to 50% of farmers interviewed. However, it is highly subsidised, thus accrues low cost and complexity (SAP provides an array of maintenance services, without which the innovation may move into the architectural category).	Incremental innovations complement current processes of production and offer specific value added that streamlines and reduces transaction costs in the process. These are relatively easily adopted and learnt by users.
	E-voucher system and Akello Banker for input packages in Uganda	These Ugandan Ministry of Agriculture and ICT-supported apps provide packages of inputs (fertilisers, chemicals and seed) to farmers. While e-vouchers use a subsidy system, paying partial costs of the inputs per growing season, Akello Banker provides discounts to farmers via its dashboard, if farmers purchase inputs from its partners, while also getting working capital loans to do so. 70% of farmers responded positively, stating that their overall input costs had reduced; however, this was not enough to offset losses incurred in logistics and final sale owing to price volatility in markets.	
Frugal (substitutes, with low cost, complexity and capabilities required)	Data-connected agriculture: SMS- and USSD-based apps, such as PAD e-Granary in Kenya	SMS and USSD apps have high uptake owing to high mobile phone penetration. Together, these apps are used by over 500,000 farmers across Kenya. Both provide real-time information on prices, weather and good agricultural practices to farmers, while supporting provision of loans and insurance. About 65% of farmers interviewed said the app reduced information asymmetry while increasing their ability to bargain for better prices with buyers.	Disruptive in terms of changing the process of production and sale and causing disintermediation; and increased bargaining ability of the farmers with buyers. Such apps are not necessarily causing behavioural shifts or norm changes.

Source: Authors; ODI key informant interviews (KIIs), April–July 2019 in Kenya and Uganda. 60 interviews performed in total.

at less than 20%. Burundi and Tanzania have the lowest access to internet within the EAC. In terms of active broadband subscriptions per 100 people, Rwanda leads, with 25% broadband penetration, followed by Uganda, Kenya, Burundi and Tanzania. Over 30% of firms in Burundi, Rwanda and Tanzania identify access to financing as a major constraint to firm operations, with only 6% of working capital in Tanzania being financed by banks. Payment solutions are largely driven by mobile accounts, with low usage of debit and credit cards (Figure 10).

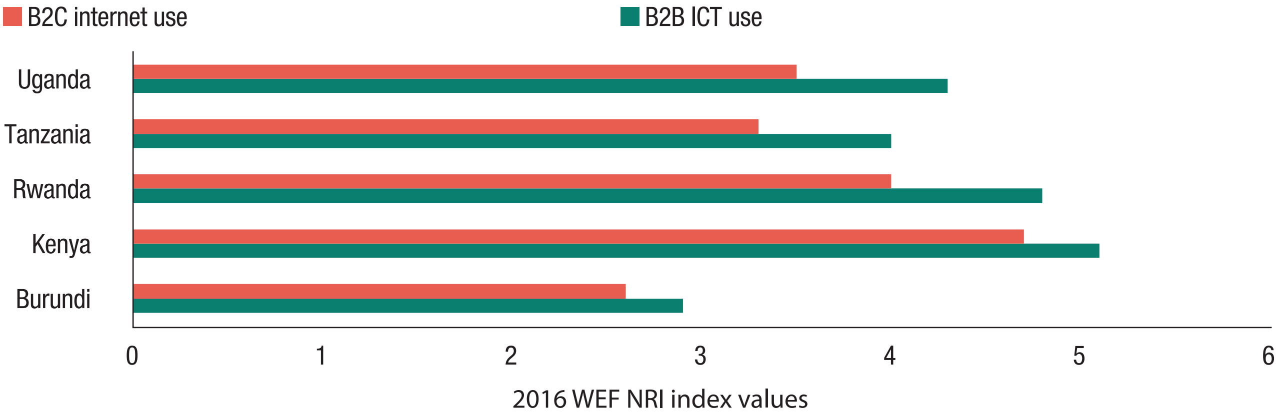
In terms of trade logistics and trade facilitation, postal reliability is higher in Tanzania, Uganda and Kenya than in Rwanda and Burundi. It takes roughly 10 to 12 days to clear customs in the EAC, except in Burundi, where the average is 20 days.

Figure 10 Indicators to measure top-down digital enablers in the EAC



Source: Authors, using World Integrated Trade Solutions (WITS, n.d.)

Figure 11 e-Commerce in the EAC



Source: Authors, using World Integrated Trade Solution data (WITS, n.d.)

Figure 11 shows that Kenya, followed by Rwanda, lead the EAC in terms of B2B ICT use and B2C internet use (WEF, n.d.). This may, in part, be explained by Kenya's more developed legal and regulatory framework. The United Nations Conference on Trade and Development Investment Policy Monitor (UNCTAD, n.d.) shows that both countries have active legislation on three key e-commerce regulatory frameworks, including e-transactions, online consumer protection and cyber-crime. They also have draft legislation on data protection and privacy. In contrast, Burundi, which ranks lowest in terms of both B2B and B2C e-commerce, does not yet have active legislation in any of the four categories.

Business ecosystem and human capital: A digitally enabling environment is also crucial for digital transformation, requiring investments in the business ecosystem and human capital development. Table 4 suggests that, within the EAC, Rwanda and Kenya rank higher in terms of ease of doing business (EODB), followed by Uganda, Tanzania, Burundi and South Sudan. In fact, Kenya and Rwanda rank in the top 10 economies globally to be showing the most notable improvement in performance on the doing business indicators. Rwanda ranks 29 in the world on the World Bank's Ease of Doing Business index 2019, with reforms in starting a business, getting electricity, registering property, getting credit, trading across borders, enforcing contracts and resolving insolvency. Interestingly, digitalisation has been a common theme in the business regulatory reforms undertaken by both Kenya and Rwanda. In Kenya, the process of providing information on valued-added tax (VAT) has been simplified through improvements in an existing online system – iTax (World Bank, 2019). The Ministry of Lands and Physical Planning has also implemented an online land rent financial management system on the eCitizen portal, which allows property owners to determine land rent, make online payments and obtain the land rates clearance certificate digitally (ibid.). Rwanda has streamlined the process of starting a business through new and free software, provided by the Revenue Authority, which allows taxpayers to issue VAT invoices. The National Agricultural Export Development Board of Rwanda has also introduced an online system, enabling issuance of electronic certificates of origin (ibid.).

Table 4 Ease of doing business in the EAC

Country	Score	EODB score change (2018–2019)
Kenya	70.31	5.25
Rwanda	77.88	4.15
Tanzania	53.63	0.34
Uganda	57.06	0.65
Burundi	47.41	0.73
South Sudan	35.34	2

Source: calculated from World Bank Ease of Doing Business database (2019)

Automation of customs is also underway in both economies, which will facilitate faster trade logistics.

The impact of digitalisation is likely to differ across sectors and tasks, depending on both the economic and the technical feasibility of automation. Globally, digitalisation is observed to be increasing the share of non-routine tasks, which tend to be performed by either high-skilled workers (e.g. cognitive tasks of data analysis) or low-skilled workers (e.g. non-cognitive tasks of cleaning), with middle-skilled workers concentrated in the provision of routine tasks. These tasks are more codifiable and easier to automate, leading to labour market polarisation, with 'hollowing-out' of the middle-skilled workers (Beaudry et al., 2016). While evidence of labour market polarisation is readily available for developed countries, the evidence for developing economies is mixed. Some countries, such as Uganda, witnessed a decreasing employment share of middle-skilled workers in the period 1995–2012, while others, such as Ethiopia and Ghana, document a decline in low-skilled employment (World Bank, 2016). Banga and te Velde (2018) highlight the case of Megh Industries, a Kenyan manufacturing firm that has also reported a decline in the share of middle-skilled workers as a result of automation, but has put in place strategies to retrain displaced workers.

While the agriculture sector is less intensive in routine tasks compared with manufacturing, increasing digitalisation of the sector within the EAC is likely to increase demand for digital skills. These include basic digital skills such as operating a mobile phone and going online; intermediate digital skills such as using emails to communicate and collaborate on digital advertising; and advanced digital skills such as mobile app development.

4.2.2 Complementary factors for AgriTech disruption: bottom-up enablers

Land rights: These include various aspects of land and agricultural policy that are critical to enabling AgriTech to function. Land rights and governance have been a contentious issue in East Africa, with ownership status remaining unclear and lack of inheritance rights for women to own property in several countries. This impinges on the asset-specific investments that farmers make in their farmland.

Cooperatives have long supported agricultural development, promoting economies of scale, greater group cohesion and better-quality inputs, and are more inclusive of women producers (Agarwal and Agrawal, 2017). Users within an AgriTech space are usually funnelled through 'area cooperatives', which are formal entities, with management systems in place at the district or county level (the largest administrative unit in a country). These area cooperatives facilitate easy access to several rural producing marketing and groups, in smaller administrative units. Thus, AgriTech firms approach area cooperatives to support implementation, and well-functioning and endowed cooperatives with organisational skills prove to be assets in the adoption and proliferation of AgriTech.

National food security acts and standards-related acts/laws are key to the uptake and adoption of AgriTech products. This is because they propel innovation in technology related to products that aim to improve the quality of the food and nutritional diversity for consumers.

5 Pathways of AgriTech disruption in the EAC

We identify six pathways through which AgriTech affects value chains and perpetuates disruption. In each case, we show the key AgriTech categorisations, and link them to how they may have the potential to engender disruption. We use our typology shown in Figure 12 to explain how each of the pathways can be actualised. It is important to reiterate that disruptive potential will depend on who is being disrupted, what the norm has been and how it has changed, and the extent to which the AgriTech complements or substitutes. In the forthcoming publications within the series we aim to perform case studies deep diving into each pathway to better understand their disruptive potential.

Pathway 1: AgriTech can lead to increased productivity in capital and labour

Increasing productivity of capital and labour is expedited through reducing information asymmetries and transaction costs for the exchange of goods. AgriTech potentially facilitates enhancing the strength and cohesiveness of networks within value chains,

Figure 12 Pathways: links to AgriTech disruption

Pathway 1	AgriTech can lead to increased productivity in capital and labour	Architectural and incremental disruption
Pathway 2	AgriTech can lead to value addition and diversification of functions	Range from radical to incremental disruption
Pathway 3	AgriTech can lead to increase in regional trade and cohesion	Architectural and incremental disruption
Pathway 4	AgriTech can lead to increase in skill acquisition and formalisation of jobs	Frugal and architectural disruption
Pathway 5	AgriTech can increase opportunities for youth and women entrepreneurs	Full range of disruptions
Pathway 6	AgriTech can be a means to improve re-distribution of value	Full range of disruptions

Source: Authors

by increasing the frequency and quality of interactions. This can reduce information asymmetry and encourage knowledge sharing between various actors in a value chain, specifically benefiting lower-tier actors like farmers, workers and youth. Furthermore, strong networks engender e-trust, which in turn can make the networks increasingly durable and stable. Productivity can be enhanced by digital value-chain management solutions such as B2B services that help agribusinesses, cooperatives, nucleus farms, and input agro-dealers connect with smallholder farmers. These digital apps lower costs through greater efficiency; improve value chain quality through better traceability and accountability; and ultimately increase smallholder farmer yields and incomes by making it easier for more commercial players to formally engage with large numbers of smallholder farmers (CTA 2018; Tsan et al., 2019, Wolfert et al., 2017).

AgriTech categorisation and disruption potential: *Data-connected devices* such as apps and digital platforms bring buyers and sellers together, enable access to high-value markets and reduce the transaction costs associated with physical markets. Thus, apps tend to complement and not replace processes, and *have been classified as architectural and incremental*.

While AgriTech, in the form of digital platforms, can reduce transaction costs (Aker and Mbiti, 2010), there is still the question of the ability of farmers to perceive the 'the usefulness or affordance' of these platforms, especially given the educational and technical barriers associated with the usability of the platform 'artefact' (Thapa and Hatakka, 2017). There is also the challenge of poor internet infrastructure, on which AgriTech as digital platforms largely depends. This also highlights underlying issues related to digital inequalities between rural and urban areas in developing regions. These technical, educational and infrastructural barriers associated with the use of AgriTech in rural agricultural processes generate a need for 'digital intermediaries' who intercede between rural farmers and digital platforms. As such, this group (rural farmers) tends to be characterised by passive participation in digital platforms (Ezeomah and Duncombe, 2019), similarly to existing power relations between farmers and farm-gate (non-digital) intermediaries, with wider implications for their data rights and privacy. The use of AgriTech in the form of digital platforms is thus double-edged. It reduces transaction costs and improves the visibility of rural farmers within the value chains in which they operate. However, it also introduces a new set of intermediaries that can replicate previous imbalanced power relations between uninformed rural farmers and opportunistic farm-gate intermediaries.

Pathway 2: AgriTech can lead to value addition and diversification of functions

AgriTech innovations create opportunities for specialisation in agricultural value chain functions, especially by supporting the servicification of agriculture. In diversifying agricultural functions beyond on-farm labour, AgriTech strengthens other value-added functions such as marketing, delivery and processing. For instance, Twiga Foods has helped revolutionise the way small kiosks stock their inventories, while at the same time providing loans, which have radically disrupted the norm, changing the behaviour and management style of numerous shop-owners across Kenya.

AgriTech categorisation and disruption potential: *Disruption can range from radical to incremental*, but issues linked to adverse incorporation and lack of incorporation of indigenous knowledge into AgriTech products may hinder users from adding value and diversifying further. For instance, using remote sensing and land mapping, farmers can begin to grow new products for new markets, thus making the most of the real-time data they obtain in relation to commodity prices, weather and land mapping. While, at the same time, the data provided to farmers may be inaccurate due to poor infrastructural support (bad quality bottom-up and top-down enablers) causing significant errors in decision-making by farmers and distrust within networks in the value chain.

Pathway 3: AgriTech can lead to increased regional trade and cohesion

The digitalisation of the agricultural trading process can decrease human error, improve communication between stakeholders along supply chains and reduce container processing times. OECD/WTO (2017) suggests that TradeMark East Africa's work in the EAC has resulted in the elimination of 87 of 112 identified non-tariff barriers, in part because of digitalisation. For instance, it supported automation of the application and issuance of certificates of origin in Kenya by the Kenya National Chamber of Commerce and Industry, resulting in an average time reduction of 86% to obtain a certificate, from 84 hours to 12 hours (ibid.). The rollout of the Customs Business Systems Enhancement Programme in Uganda also reduced clearance times from five to two days, enabling costs savings of $300 per customs declaration. The construction of the Busia One Stop Border Post in Uganda further resulted in a reduction in the average time to cross from Busia, Uganda, to Busia, Kenya, by 80% (ibid.).

AgriTech categorisation and disruption potential: This most commonly involves AgriTech linked to data-connected devices (new platforms for regional trade and data collection and use), automation (of routine tasks involving paperwork) and smart warehousing and logistic tech (blockchains), which aggregate varied requirements into a single portal that is transparent and easy to access and maintains histories of each individual involved. These technologies are generally complements to existing processes, and do not necessarily change the modus operandi. Rather, they improve efficiency, and thus are primarily classified as architectural and incremental disruptions.

Pathway 4: AgriTech can lead to increased skill acquisition and formalisation of jobs

AgriTech is introducing new forms of skill sets to the agriculture sector in Africa. As agriculture become more digitalised and formalised, technical skills such as the operation of drones, platforms and automated systems will be increasingly sought after. Currently, agriculture in East Africa is still characterised by large numbers of rural farmers whose average age is over 50 years with little formal secondary education (White, 2012). On the one hand, the use of some forms of AgriTech could pose technical and financial challenges to rural farmers, while opening up the sector to highly skilled groups on the other hand. Across all the AgriTech types, from data-connected agriculture to biotechnology, several new education centres and training programmes (including the GSMA Ecosystem Accelerator which aims to build synergies between starts-ups and mobile operators, the CTA youth incubator (CTA, 2019) and co-working spaces such as Outbox in Uganda and iHub in Kenya) have been set up to engender skill diffusion and training. Registering on AgriTech platforms and collection of data histories enables keeping records of the creditworthiness of farmers, youth and women who previously may not have been eligible for working capital or personal loans. For example, Sauti, a mobile-based cross-border trading platform for women, provides information on their rights, the required customs procedures and documentation, making them less vulnerable to corruption and harassment (Sauti Africa, n.d.). They collect SMS and USSD trade and market data and provide big data analytics in real time. This has brought many women who relied on the informal market to more formal settings.

AgriTech categorisation and disruption potential: These types of disruption may range from frugal – as they may involve low costs but provide new markets and new ways of trading with different countries across the border – to more architectural, when they complement processes but are expensive and complex.

Pathway 5: AgriTech can increase opportunities for youth and women entrepreneurs

AgriTech has opened up opportunities for educated youth to participate in agriculture by appealing to the 'tech-savvy' aspect of young East Africans who are currently innovating to add value to agricultural value-chain activities. Secondary data collected suggests the average age of agri-preneurs is between 29 and 34 in the EAC; however, there are generally far fewer women than men (Table 5).

Table 5 Youth and women in AgriTech in the EAC

Characteristic	Kenya	Uganda	Tanzania	Rwanda	South Sudan	Burundi
Average age of owner	33	31	29	31	34	32
Gender of owner (number)	Male: 26 Female: 6	Male: 11 Female: 3	Male: 10 Female: 0	Male: 4 Female: 2	Male: 4 Female: 0	Male: 4 Female: 0
Size of company (average)	11–50	11–50	11–50	11–50	1–10	1–10
Ownership	Local: 25% Foreign: 75%	Local: 70% Foreign: 30%	Local: 30% Foreign: 70%	Local: 33% Foreign: 66%	Local: 25% Foreign: 75%	Local: 25% Foreign: 75%

Note: Total = 70 companies across the EAC.
Source: data collated by ODI

Pathway 6: AgriTech can be a means to improve redistribution of value

Technology, by its nature, supports the creation of value; however, disruptive innovation comes at a cost to *agency*, in terms of the inevitable displacement of actors or the unplanned restructuring of business models (Yu and Hang, 2010). This 'cost to agency' should be central in debates around the disruptive potential of AgriTech in developing regions, especially where institutional constraints to adoption and use of technology prevail. While disruptive innovation increases the competitive advantage of innovators and adopters, it can also be competency-destroying to other value-chain actors who are unable to adopt such innovations. Disruptive innovation can lead to the restructuring of how value is created and where value is captured in a value chain (Bowman and Ambrosini, 2000), especially when new actors are introduced (Schuelke-Leech, 2017). In East Africa, there is evidence that most AgriTech being introduced into agricultural value chains is developed by start-ups comprising young innovators who are new actors in these value chains. Through their AgriTech innovations, these actors create new value and also capture a share of this for their businesses and investors. There is, however, as yet no clear understanding of how value is redistributed as a result of the introduction of new actors and innovations, given the paucity of data on the use of AgriTech in developing country agriculture.

There is a need to a create a global reporting standard for AgriTech products, so as to be able to benchmark results, integrate data with fiscal policy (taxation) and map the creation of new global wealth chains. This will make it possible to understand areas where there is 'surplus value capture', not only as money but also as learning and knowledge accumulation. The understanding of where 'surpluses' are being created can help identify potential spaces for redistribution. Technologies such as blockchains can go a long way towards creating increased transparency in the system; however, such technologies are still resource intensive and have yet to be scaled.

6 The way forward: summary and next steps

This paper has sought to explore what disruption means within AgriTech by explaining what it is, who may be disrupted, how it occurs and the pathways along which it is achieved. We find that disruption is a sliding scale, which is contextualised, experienced and understood differently by different actors along the value chain.

Overall, the aim is to better understand the extent to which AgriTech carries a disruptive potential and how it can promote agricultural, digital and economic transformation within countries, with a specific emphasis on the EAC. The main building blocks of AgriTech – hardware, software and data chains – are amalgamated to form five AgriTech categorisations: data-connected devices, agricultural biotechnology and biochemistry, farm robotics and automation, and innovative food and farming systems.

There are five key elements to take away from this report:

1. AgriTech categorisations: five types are identified, including (1) digital ag using ICT, internet and AI, primarily driven by software development; (2) ag biochemistry and biotechnology, harnessing the strengths of biotech and bioengineering; (3) innovative food and farming, which unlock new systems of planting and food alternatives; (4) farm robotics and automation, drawing on mechanical and electronic engineering coupled with AI; and (5) smart warehousing and logistics, consisting of the use of blockchains, fleet optimisation software and ERP.
2. Characteristics of AgriTech that promote or hinder adoption: characterising AgriTech to define the possibility of adoption and therefore the transformational effect it has on users is described through the 3Cs of cost, complexity and capabilities. The adoption of AgriTech depends on its affordability. Its complexity – whether users are able to decode and use it – is another factor. In general, relatively low-complexity technologies that are easier to adopt will be more likely to replace routine low-skill tasks than precision high-skill tasks. The capabilities of users to understand and use products represent a critical aspect to comprehend the scope and depth of possible disruption.
3. Disruption is on a sliding scale: it can either 'replace/substitute' or 'complement'. Disruption can have a substitution effect if it displaces existing practices in a sector or value chain and causes behavioural change that ultimately leads to changing underlying the norms and culture of society. It is more complementary if it supplements existing products, processes and business models.
4. Disruption types: Combining the 3Cs and the sliding scale of disruption gives us four types of disruptive AgriTech:
   - Radical (takes place when products, processes and models kick start new industries (or swallow existing ones), and involves adopting revolutionary technology and changes to behaviour and societal norms)
   - Architectural (often described as developing complementary products/processes or modifying existing forms of AgriTech in specific sectors)
   - Incremental (the most common form: products and processes are tweaked, improved and complemented by related products and processes)

- Frugal (involves substitution – i.e. by discovering new business models, reconfiguring value chains and redesigning products to serve users who face extreme affordability constraints, in a scalable and sustainable manner).

5. Pathways in AgriTech can cause disruption: the disruption types allow the identification of pathways through which AgriTech disrupts production and trade. AgriTech can create several paradoxes, generating both positive and negative implications. AgriTech has the potential through these four types of disruption to increase productivity and alter value addition, leading to a refunctionalisation of the production tasks, regionalisation of trade and cohesion and improved and redefined skill sets – and possibly improved gender equity and youth participation in the workforce. It can also lead to challenges by compounding social and economic inequalities, create new trade barriers and requirements, generate new powerful firms that control 'value' in the chain and appropriate from the more marginalised.

Thus, there is a need for policy-makers first to comprehend the possibility of adoption and proliferation of AgriTech and what type of disruption could arise; and then to create equitable policies across agriculture, the digital space, trade and gender to create a common 'policy space' to create inclusive institutional configurations.

References

Abernathy, W.J. and James, M.U. (1978) 'Patterns of industrial innovation' *Technology Review* 64: 254–228

ACACIA – Alliance for Accelerated Crop Improvement in Africa (n.d.) 'ACACIA'. Alliance for Accelerated Crop Improvement in Africa. Webpage. ACACIA (acaciaafrica.org/about)

ACRE Africa (n.d.) 'Our achievements'. Webpage. ACRE Africa (acreafrica.com/achievements)

AU – African Union (2014) Malabo declaration on accelerated agricultural growth and transformation for shared prosperity and improved livelihoods. Adopted 27 June 2014

Agarwal, B. and Agrawal, A. (2017) 'Do farmers really like farming? Indian farmers in transition' *Oxford Development Studies* 45(4): 460–478

AgFunder (2018) *AgFunder AgriFood Tech investing report 2018*. San Francisco CA: AgFunder (agfunder.com/research/agrifood-tech-investing-report-2018)

AgriProtein (n.d.) 'AgriProtein'. Webpage. AgriProtein (agriprotein.com)

Ahuja, S. and Chan, Y.E. (2016) 'Digital platforms for innovation in frugal ecosystems' *Academy of Management Proceedings* 2016(1): 17007

Aker, J.C. (2011) 'Dial "A" for agriculture: a review of information and communication technologies for agricultural extension in developing countries' *Agricultural Economics* 42(6): 631–647

Aker, J.C. and Mbiti, I.M. (2010) 'Mobile phones and economic development in Africa' *Journal of Economic Perspectives* 24(3): 207–232

Andal-Ancion, A., Cartwright, P.A. and Yip, G.S. (2003) 'The digital transformation of traditional business' *MIT Sloan Management Review* 44(4): 34–41

Anderson, P. and Tushman, M.L. (1990) 'Technological discontinuities and dominant designs: a cyclical model of technological change' *Administrative Science Quarterly* 35(4): 604–633

ASBCB (n.d.) 'About our society'. Webpage. African Society for Bioinformatics and Computational Biology (www.asbcb.org/about.php)

Banga, K. and te Velde, D.W. (2018) *How to grow manufacturing and create jobs in a digital economy: 10 policy priorities for Kenya*. London: Supporting Economic Transformation (set.odi.org/wp-content/uploads/2018/11/10-policy-priorities-Kenya-digital-economy_Final-New.pdf)

Barrientos, S. (2014) 'Gendered global production networks: analysis of cocoa–chocolate sourcing' *Regional Studies* 48(5): 791–803

Bay, E.G. (ed.) (2019) *Women and work in Africa*. London: Routledge

Beaudry, P., Green, D.A. and Sand, B.M. (2016) 'The great reversal in the demand for skill and cognitive tasks' *Journal of Labor Economics* 34(S1): S199–S247

Belmaachi, L. (2018) 'African Agtech Market Map: 99 technologies changing the future of agriculture in Africa'. AgFunder News, 14 February (agfundernews.com/african-agtech-market-map.html)

Bhatti, Y.A. (2016) 'Towards a theory of frugal innovation: what is frugal, what is innovation?' *Academy of Management Proceedings* 2016(1): 10794

Boateng, R., Budu, J., Mbrokoh, A.S., Ansong, E., Boateng, S.L. and Anderson, A.B. (2017) *Digital enterprises in Africa: a synthesis of current evidence*. DIODE Working Paper 2. Manchester: Centre for Development Informatics, The University of Manchester (diodeweb.files.wordpress.com/2017/04/diode-paper-2-digital-enterprises-in-africa.pdf)

Bowman, C. and Ambrosini, V. (2000) 'Value creation versus value capture: towards a coherent definition of value in strategy' *British Journal of Management* 11(1): 1–15

Christensen, C.M. (1997) *The innovator's dilemma: when new technologies cause great firms to fail*. Cambridge MA: Harvard Business Review Press

Christensen, C.M. and Raynor, M. (2003) *The innovator's solution: creating and sustaining successful growth*. Cambridge MA: Harvard Business School Press

Cohen, W.M. and Levinthal, D.A. (2000) 'Absorptive capacity: a new perspective on learning and innovation' in R.L. Cross and S. Israelit (eds.) *Strategic learning in a knowledge economy*. Woburn MA: Butterworth-Heinemann

Communicaffe International (2017) 'Blockchain traceable coffee: bext360 partners in Africa, Europe and N.A.'. Communicaffe International, 2 November (https://www.comunicaffe.com/blockchain-traceable-coffee-bext360-partners-in-africa-europe-and-n-a)

CTA – The Technical Centre for Agricultural and Rural Co-operation (2019) 'Kenya to build Africa's first agri-tech innovation incubator in 3 years' Press review. CTA (https://spore.cta.int/en/press-reviews/article/kenya-to-build-africa-s-first-agritech-innovation-incubator-in-three-years-sid0470f1a72-510e-47dd-a0ba-9eee1dd5bf37)

Dahlin, K.B. and Behrens, D.M. (2005) 'When is an invention really radical? Defining and measuring technological radicalness' *Research Policy* 34(5): 717–737

Danaei, G., Andrews, K. G., Sudfeld, C. R., Fink, G., McCoy, D. C., Peet, E., … Fawzi, W. W. (2016) 'Risk factors for childhood stunting in 137 developing countries: a comparative risk assessment analysis at global, regional, and country levels' *PLoS Medicine* 13(11)

Deichmann, U., Goyal, A. and Mishra, D. (2016) *Will digital technologies transform agriculture in developing countries?* Washington DC: World Bank

Deloitte (2017) *Continuous interconnected supply chain: using blockchain and internet of things in supply chain traceability*. London: Deloitte Touche Tohmatsu Limited (www2.deloitte.com/content/dam/Deloitte/lu/Documents/technology/lu-blockchain-internet-things-supply-chain-traceability.pdf)

Duvenage, E. (2017) 'Institute for Grape and Wine Sciences celebrates success of its first five years'. Stellenbosch University, 8 February (www.sun.ac.za/english/Lists/news/DispForm.aspx?ID=4640)

Elferink, M. and Schierhorn, F. (2016) 'Global demand for food is rising. Can we meet it?' Harvard Business Review, 7 April (hbr.org/2016/04/global-demand-for-food-is-rising-can-we-meet-it)

Ernst, D. and Kim, L. (2002) 'Global production networks, knowledge diffusion, and local capability formation' *Research Policy* 31(8): 1417–1429

EVAD – Export Value Added Database (n.d.) 'Export Value Added Database' (electronic database, World Bank) (https://datacatalog.worldbank.org/dataset/export-value-added-database)

Ezeomah, B. and Duncombe, R. (2019) 'The role of digital platforms in disrupting agricultural value chains in developing countries' in P. Nielsen and H. Kimaro (eds) *Information and communication technologies for development. Strengthening southern-driven cooperation as a catalyst for ICT4D*. London: Springer

Foster, C., Graham, M., Mann, L., Waema, T. and Friederici, N. (2018) 'Digital control in value chains: challenges of connectivity for East African firms' *Economic Geography* 94(1): 68–86

Gawer, A. (2014) 'Bridging differing perspectives on technological platforms: toward an integrative framework' *Research Policy* 43(7): 1239–1249

GIS Resources (2016) 'Tanzania introduces remote sensing technology for crop monitoring'. GIS Resources, 22 February (www.gisresources.com/tanzania-introduces-remote-sensing-technology-for-crop-monitoring)

GSMA – Groupe Speciale Mobile Association (n.d.) 'Innovation fund'. Webpage. GSMA (www.gsma.com/mobilefordevelopment/eainnovationfund)

GSMA (2018) *The mobile economy: sub-Saharan Africa 2018*. London: GSMA Intelligence (www.gsmaintelligence.com/research/?file=809c442550e5487f3b1d025fdc70e23b)

Herrero, M., Thornton, P.K., Notenbaert, A.M., Wood, S., Msangi, S., Freeman, H.A., … and Lynam, J. (2010) 'Smart investments in sustainable food production: revisiting mixed crop-livestock systems' *Science* 327(5967): 822–825

Hickey, S. (2013) *Thinking about the politics of inclusive development: towards a relational approach*. ESID Working Paper 1. Manchester: Effective States and Inclusive Development Research Centre, The University of Manchester

Hitch, J. (2019) 'It's about time: welcome to the "now" economy and smart warehouses'. Industry Week, 18 January (www.industryweek.com/technology-and-iiot/its-about-time-welcome-now-economy-and-smart-warehouses)
Howell, R., van Beers, C. and Doorn, N. (2018) 'Value capture and value creation: the role of information technology in business models for frugal innovations in Africa' *Technological Forecasting and Social Change* 131: 227–239
IFPRI – International Food Policy Research Institute (2019) 'Agricultural Total Factor Productivity (TFP), 1991-2015: 2019 Global Food Policy Report Annex Table 4' (electronic data set, IFPRI) (http://www.ifpri.org/publication/agricultural-total-factor-productivity-tfp-1991-2015-2019-global-food-policy-report)
Iizumi, T. and Ramankutty, N. (2015) 'How do weather and climate influence cropping area and intensity?' *Global Food Security* 4: 46–50
iProcure (n.d.) 'Shaping technology supply chain'. Webpage. iProcure (iprocu.re)
Jain, R., Arora, A. and Raju, S. (2009) 'A novel adoption index of selected agricultural technologies: linkages with infrastructure and productivity' *Agricultural Economics Research Review* 22(1): 109–120
Joshi, N. (2019) '7 types of artificial intelligence'. Forbes, 19 June (www.forbes.com/sites/cognitiveworld/2019/06/19/7-types-of-artificial-intelligence/#4f912b54233e)
Kabeer, N. (2019) 'Randomized control trials and qualitative evaluations of a multifaceted programme for women in extreme poverty: empirical findings and methodological reflections' *Journal of Human Development and Capabilities* 20(2): 197–217
Kabubo-Mariara, J. and Karanja, F.K. (2007) 'The economic impact of climate change on Kenyan crop agriculture: a Ricardian approach' *Global and Planetary Change* 57(3): 319–330
Karikari, T., Quansah, E. and Mohamed, W.M.Y. (2015) 'Widening participation would be key in enhancing bioinformatics and genomics research in Africa' *Applied & Translational Genomics* 6: 35–41
Kazan, E., Tan, C.W. and Lim, E.T. (2014) 'Towards a framework of digital platform disruption: a comparative study of centralized & decentralized digital payment providers'. Presentation at the 25th Australasian Conference on Information Systems, 8–10 December, Auckland, New Zealand (openrepository.aut.ac.nz/handle/10292/8052)
Knapp, A. (2018) 'AgTech Bext360 raises $3.35 million to provide traceability to commodities'. Forbes, 1 June (www.forbes.com/sites/alexknapp/2018/06/01/agtech-blockchain-startup-bext360-raises-3-35-million-to-provide-traceability-to-commodities/#7de8d8806d25)
Koskinen, K., Bonina, C. and Eaton, B. (2018) *Digital platforms in the global South: foundations and research agenda*. Diode Paper 8. Manchester: University of Manchester
Kuijpers, R. and Swinnen, J. (2016) 'Value chains and technology transfer to agriculture in developing and emerging economies' *American Journal of Agricultural Economics* 98(5): 1403–1418
Liversidge, G. (2015) 'Christensen's disruptive innovation and Schumpeter's creative destruction' *Otsuma Women's University Bulletin* 47: 248–231
Lobell, D.B. and Field, C.B. (2007) 'Global scale climate–crop yield relationships and the impacts of recent warming' *Environmental Research Letters* 2(1): 014002
Markard, J. and Truffer, B. (2008) 'Technological innovation systems and the multi-level perspective: towards an integrated framework' *Research Policy* 37(4): 596–615
Mwangi, M. and Kariuki, S. (2015) 'Factors determining adoption of new agricultural technology by smallholder farmers in developing countries' *Journal of Economics and Sustainable Development* 6(5): 208–216
Mwebaze, C.E. (2018) 'Sustainable water use in Lake Edward-George Basin: a case study of River Mubuku-Sebwe sub catchments' (MSc thesis, Makerere University)
Nagy, D., Schuessler, J. and Dubinsky, A. (2016) 'Defining and identifying disruptive innovations' *Industrial Marketing Management* 57: 119–126

Neef, A. and Neubert, D. (2011) 'Stakeholder participation in agricultural research projects: a conceptual framework for reflection and decision-making' *Agriculture and Human Values* 28(2): 179–194

OECD/WTO – Organisation for Economic Co-Operation and Development/World Trade Organisation (2017) *Aid for trade at a glance 2017: promoting trade, inclusiveness and connectivity for sustainable development*. Paris, Geneva: OECD, WTO

Oliver, Y., Robertson, M. and Wong, M. (2010) 'Integrating farmer knowledge, precision agriculture tools, and crop simulation modelling to evaluate management options for poor-performing patches in cropping fields' *European Journal of Agronomy* 32(1): 40–50

PAD – Precision Agriculture for Development (n.d.) 'Empowering farmers with digital agriculture'. Webpage. Precision Agriculture for Development (precisionag.org)

Partech (2018) *2018 was a monumental year for African tech start-ups, with US$ 1.163 billion raised in equity funding, a 108% YoY growth*. Partech Africa Team Report. Nairobi: Partech (partechpartners.com/documents/6/2019.03.22_-_Africa_Tech_Startups_raises_1.163B_in_2018_Partech-Report_nQIOkE7.pdf)

Pingali, P. (2019) 'Policies for sustainable food systems' in C. Campanhola and S. Pandey (eds.) *Sustainable food and agriculture*. Cambridge MA: Academic Press

Price, S. (2018) 'Putting digital technologies in the hands of farmers'. Webpage. CTA (spore.cta.int/en/publications/all/issue/putting-digital-technology-in-farmers-hands-sid0e3121604-cf0f-4b7a-9d93-01a9da2087ae)

Prinsloo, T. and de Villiers, C. (2017) 'A framework to define the impact of sustainable ICT for agriculture projects: the Namibian livestock traceability system' *The Electronic Journal of Information Systems in Developing Countries* 82(1): 1–22

Quisumbing, A.R., Brown, L.R., Feldstein, H.S., Haddad, L. and Peña, C. (1996) 'Women: the key to food security' *Food and Nutrition Bulletin* 17(1): 1–2

Reid, J.F. (2011) 'The impact of mechanization on agriculture' *Bridge* 41(3): 22–29

Rodrik, D. (2016) 'Premature deindustrialization' *Journal of Economic Growth* 21(1): 1–33

Rogers, E.M. (1995) *Diffusion of innovations*. New York NY: Free Press

Sammut-Bonnici, T. and Paroutis, S. (2013) 'Developing a dominant logic of strategic innovation' *Management Research Review*, 36(10): 924–938

Sauti Africa (n.d.) 'Our approach'. Webpage. Sauti Africa (sautiafrica.org/our-approach)

Schmidt, G.M. and Druehl, C.T. (2008) 'When is a disruptive innovation disruptive?' *Journal of Product Innovation Management* 25(4): 347–369

Schuelke-Leech, B.A. (2017) 'A model for understanding the orders of magnitude of disruptive technologies' *Technological Forecasting and Social Change* 129: 261–274

Schumpeter, J. (1942) *Capitalism, socialism and democracy*. New York, London: Harper & Brothers

Schut, M., Cadilhon, J.J., Misiko, M. and Dror, I. (2018) 'Do mature innovation platforms make a difference in agricultural research for development? A meta-analysis of case studies' *Experimental Agriculture* 54(1): 96–119

SNV (n.d.) 'Smart water for agriculture'. Webpage. (www.snv.org/project/smart-water-agriculture-swa)

Staritz, C. and Whitfield, L. (2019) 'Light manufacturing in Ethiopia: the apparel export industry' in F. Cheru, C. Cramer and A. Oqubay (eds.) *The Oxford handbook of the Ethiopian economy*. Oxford: Oxford University Press

Stein, C. and Barron, J. (2017) *Mapping actors along value chains: integrating visual network research and participatory statistics into value chain analysis*. Colombo: International Water Management Institute

Sylvester, G. (ed.) (2019) *E-agriculture in action: blockchain for agriculture. Opportunities and challenges*. Bangkok: FAO and ITU

Tey, Y.S. and Brindal, M. (2012) 'Factors influencing the adoption of precision agricultural technologies: a review for policy implications' *Precision Agriculture* 13(6): 713–730

Thapa, D. and Hatakka, M. (2017) 'Understanding ICT in ICT4D: an affordance perspective'. Presentation at the Hawaii International Conference on System Sciences (HICSS), 4–7 January, Hawaii (scholarspace.manoa.hawaii.edu/bitstream/10125/41472/1/paper0323.pdf)
ThirdEye (n.d.) 'ThirdEye: Flying sensors to support farmers' decision making'. Webpage. ThirdEye (http://www.thirdeyewater.com)
Tiwana, A. (2013) *Platform ecosystems: aligning architecture, governance, and strategy*. Burlington, MA: Morgan Kaufmann
Tsan, M., Totapally, S., Hailu, M. and Addom, B.K. (2019) *The digitalisation of African agriculture report, 2018–2019*. Wageningen: CTA (www.cta.int/en/digitalisation-agriculture-africa)
Twiga (n.d.) 'Our story'. Webpage. Twiga Foods Limited (twiga.ke/twiga-story)
UNCTAD – United Nations Conference on Trade and Development (n.d.) 'Investment Policy Monitor' (electronic dataset, United Nations Conference on Trade and Development) (https://unctad.org/en/pages/publications/Investment-Policy-Monitor.aspx)
UNDP – United Nations Development Programme (n.d.) 'Human Development Data - gender inequality index' (electronic dataset, UNDP) (http://hdr.undp.org/en/composite/GII)
Waema, M.T. and Ndung'u, N.M. (2013) *Understanding what is happening in ICT in Kenya: a supply and demand side analysis of the ICT sector*. Evidence for ICT Policy Action Policy Paper 9. Cape Town: Research ICT Africa.
Webb, N.P., Marshall, N.A., Stringer, L.C., Reed, M.S., Chappell, A. and Herrick, J.E. (2017) 'Land degradation and climate change: building climate resilience in agriculture' *Frontiers in Ecology and the Environment* 15(8): 450–459
White, B. (2012) 'Agriculture and the generation problem: rural youth, employment and the future of farming'. *IDS Bulletin*, 43(6): 9–19
WITS (n.d.) 'World Integrated Trade Solution' (electronic dataset, UNCTAD, World Bank, UNSD, WTO, International Trade Centre) (https://wits.worldbank.org)
Wolfert, S., Ge, L., Verdouw, C. and Bogaardt, M.J. (2017) 'Big data in smart farming–a review' *Agricultural Systems* 153: 69–80
World Bank (n.d.) 'World Development Indicators' (electronic dataset, World Bank) (http://datatopics.worldbank.org/world-development-indicators/)
World Bank (2016) *World development report 2016: digital dividends*. Washington DC: World Bank
World Bank (2019) *Doing Business 2019: Training for reform*. Washington DC: World Bank
WEF – World Economic Forum (n.d.) 'Networked Readiness Index' (electronic dataset, WEF) (http://reports.weforum.org/global-information-technology-report-2016/networked-readiness-index/)
WTO – World Trade Organization (2019) 'Symposium on the role of trade in the global agri-food system'. Webpage. WTO (www.wto.org/english/tratop_e/agric_e/symposium_ag_agri_food_system_e.htm)
Yoo, Y., Boland, R.J., Lyytinen, K. and Majchrzak, A. (2012) 'Organizing for innovation in the digitized world' *Organization Science* 23(5): 1398–1408
Yu, D. and Hang, C.C. (2010) 'A reflective review of disruptive innovation theory' *International Journal of Management Reviews* 12(4): 435–452
Zhang, N., Wang, M. and Wang, N. (2002) 'Precision agriculture—a worldwide overview' *Computers and Electronics in Agriculture* 36(2–3): 113–132

Annex 1 Selected stakeholders in AgriTech in EAC

Table A1 Stakeholders in AgriTech in Kenya, Rwanda, Uganda, Tanzania, South Sudan, Burundi

Stakeholder	Type of stakeholder	Examples of stakeholders	Product/Service provided	Areas of support to farmers	Countries of operation
Vertical	Start-up	WeFarm	Digital platform for crowdsourcing agricultural information	Agricultural information service	Kenya, Tanzania, Uganda
Vertical	Start-up	iProcure	Procurement of agricultural inputs; funded by Invested Development, US	Input supply	Kenya
Vertical	Start-up	Twiga Foods	Mobile-based platform for Intermediation in FFV value chain	Aggregation and distribution	Kenya
Vertical	Start-up	Illuminum Greenhouses	Construction and distribution of remote-controllable greenhouses to small-scale farmers	Agricultural production	Kenya
Vertical	Start-up	FarmDrive	Data analytics platform for credit-scoring system supporting linkages between smallholders and financial institutions	Agricultural finance	Kenya
Vertical	Start-up	UjuziKilimo	Access to precision farming data	Information delivery	Kenya
Vertical	Start-up	Taimba	Mobile-based platform for connecting farmers to retailers	Marketing services	Kenya
Vertical	Start-up	BazaFarm	Precision farming technology: Smart agro-chemical sprayers; sensors, IoT	Agricultural production	Rwanda
Vertical	Start-up	SmAAgri	Precision farming technology; automated irrigation systems	Agricultural production	Rwanda
Vertical	Farmer cooperative	IPoVaF	Mobile-based platform for cooperative development and member integration in Irish potato value chains	Agricultural information, peer-to-peer communication and value-chain integration	Rwanda
Vertical	Input suppliers (international/ local/regional)	Syngenta	Improved seeds and agro-chemical supply	Input supply for agricultural production	Kenya, Tanzania
Vertical	Input suppliers (international/ local/regional)	Monsanto	Improved seeds and agro-chemical supply	Input supply for agricultural production	Kenya, Uganda, Tanzania
Vertical	Data aggregators	Esoko	Mobile-based platforms for data collection from rural farmers and also provide agricultural information to value chain actors in East Africa.	Agricultural information delivery; market linkages	Kenya, Uganda, Tanzania

Stakeholder	Type of stakeholder	Examples of stakeholders	Product/Service provided	Areas of support to farmers	Countries of operation
Vertical	Data aggregators	Regional Agriculture Trade Intelligence Network (RATIN)	Market data provision across national and International supply chains	Market information	Kenya
Vertical	Data aggregators	M-Trader Faida	Supply chain data aggregation application developed and implemented in partnership with Airtel and Umati Capital	Data aggregation, analysis and distribution	Kenya
Vertical	Data analytics providers	GeoFarmer	Precision farming information system; smallholder farm data aggregation and analysis. It was developed by Z_GIS at University of Salzburg and the International Center for tropical Agriculture (CIAT)	Agricultural information	Tanzania and Uganda
Horizontal	National Government	Kenyan Government	East African Marine System (TEAMS) undersea fibre cable and the National Optic Fibre Backbone Infrastructure (NOFBI)	Mobile and internet connectivity connecting rural and urban areas	Kenya
Horizontal	National Government	Ministry of Agriculture, Livestock and Fisheries	Content provision for iKilimo – mobile app and SMS platform for information service delivery implemented in partnership with Avallain Foundation, Switzerland	Agro-advisory information delivery to smallholder farmers	Kenya
Horizontal	National Government	Ministry of Water and Environment, Uganda Makerere University, Uganda	Content providers for the Climate Change Adaption and ICT (CHAI) initiative to strengthen the resilience of pastoralist to climate change. Implemented in partnership with FHI 360, US	Agro-advisory information delivery on weather and market information	Uganda
Horizontal	National Government Parastatal	Tanzania Meteorological Agency (TMA)	Content providers for the Tigo Kilimo Agri VAS platform, implemented in partnership with TechnoServe and Tigo Tanzania (one of Tanzania's largest telecom providers)	Agro-advisory information delivery	Uganda
Horizontal	CSO/NGOs	TechnoServe	Connected farmer mobile-based application supporting agribusiness linkages between farmers and other value chain actors AgriManagr – funded in partnership Food Trade ESA, UK Heifer International, and Virtual City as the developer	Agricultural marketing; supply chain management Agricultural management system that monitors aggregation and payment for agricultural commodities	Kenya and Tanzania Tanzania
Horizontal	National NGO	FIT Uganda Limited	Implementers of Infotrade – SMS platform for market price	Agricultural price information	Uganda
Horizontal	National NGO	Goal Uganda	Funders of the Infotrade platform (above)	Agricultural price information	Uganda
Horizontal	Donors and DFIs	FAO	Technical support on AgriTech initiatives; research; policy influence, financial aid	Improved farming techniques; research diffusion; market linkage	Kenya, Rwanda, Tanzania, Uganda and Burundi
Horizontal	Donor and development agencies	Syngenta Foundation	ACRE Africa initiative implemented in partnership with Safaricom	Agricultura insurance for smallholder farmers	Kenya

Stakeholder	Type of stakeholder	Examples of stakeholders	Product/Service provided	Areas of support to farmers	Countries of operation
Horizontal	Donor and development agencies	DFID	Financial aid for AgriTech programmes	Improved farming techniques; research diffusion; market linkage	Kenya, Rwanda, Tanzania, Uganda and Burundi
Horizontal	Donor and development agencies	USAID	Financial aid and technical backstopping of for AgriTech programmes AgriTech Initiative: Connected Farmer is a supply chain management system which adopts a business-to-business-to-customer (B2B2C) model; developed in partnership with TechnoServe and implemented in partnership with Vodafone	Strengthening linkages between farmers and agribusiness along agricultural value chains using a B2B2C model	Kenya and Tanzania
Horizontal	Donor and development agencies	FHI 360	Climate Change Adaption and ICT (CHAI) initiative to strengthen the resilience of pastoralist to climate change. Implemented in partnership with the Ugandan Government and the International Development Research Centre (IDRC), Canada	Agro-advisory information delivery on weather and market information	Uganda
Horizontal	Donor and development agencies	Mercy Corps	Funders of the Infotrade platform	Agricultural market price	Uganda
Horizontal	Donor and development agencies	Avallain Foundation, Switzerland	Implementers of iKilimo – mobile app and SMS platform for information service delivery	Agro-advisory information delivery	Kenya
Horizontal	Donor and development agencies	GSMA	Ecosystem Accelerator Investment Fund to support tech start-ups across Africa. Global research on ICT4D; Digital inclusion and implementation of M4D programmes	Improved farming techniques; Research diffusion; market linkage	Kenya, Rwanda, Tanzania, Uganda and Burundi
Horizontal	Development Agency	Centre for Agriculture and Biosciences International	Agricultural information delivery; strengthening plant health systems AgriTech initiative: Plantwise knowledge programme; Airtel Kilimo VAS	Agro-advisory initiative for smallholder agricultural production, Value-chain integration	Kenya and Uganda
Horizontal	Donor and development agencies	CTA	R&D initiatives on agricultural value-chain digitisation and integration; Youth and Gender Empowerment through AgriTech Agritech initiatives include:	Agricultural production, market linkages, information delivery, value-chain inclusion	Kenya, Rwanda, Tanzania, Uganda and Burundi
Horizontal	Foundations	Syngenta Foundation	ACRE Africa initiative in partnership with Safaricom to develop a digital payment system to provide insurance for farmers Farmforce initiative to improve commodity traceability along agricultural value chains	Agricultural finance (insurance Supporting farmers in meeting food standards and linking farmers to high-value chains	Kenya Uganda

Stakeholder	Type of stakeholder	Examples of stakeholders	Product/Service provided	Areas of support to farmers	Countries of operation
Horizontal	Foundations	Safaricom	iCow – Cattle tracking and management information system using phone feature and SMS M-Farm: also supported by Airtel	Agro-advisory Information delivery and value-chain integration	Kenya
Horizontal	Private financial institutions (venture capital, angel investors, Private equity)	TLcom Capital; GAFSP; Omidyar Network; True Ventures; Accelerated Digital; LocalGlobe; Safaricom Foundation; Invested Development	Venture capitalists providing seed funding; incubator and accelerator programmes to support AgriTech business initiatives AgriTech start-up supported: Twiga Foods; WeFarm; iProcure	Supporting AgriTech start-up business initiatives	Kenya; Tanzania; Uganda; Rwanda
Horizontal	Banks (international/ operating locally)	World Bank	Digital platform to support funding of AgriTech innovations	AgriTech initiative funding	Kenya;
Vertical	Companies providing infrastructure (electricity, ICT, internet cables)	Safaricom	Mobile network services (data and voice); money transfer (M-PESA).	Supporting B2B payments from farmers to input suppliers; and payment for agricultural commodities	Kenya, Tanzania and Uganda
Vertical	Mobile Network Operators (MNOs)	MTN; Airtel; Vodafone	Mobile and internet services; sponsoring AgriTech development initiatives such as app competitions etc	Supporting USSD messaging to rural farmers on management techniques; early warning systems (weather forecast; pest and disease outbreaks)	Kenya; Uganda; Rwanda; Tanzania
Vertical	Mobile Network Operators (MNOs)	Tigo Kilimo	The Tigo Kilimo Agri VAS platform, provides agricultural information on market price, farming techniques, etc.	Agro-advisory information delivery	Uganda
Horizontal	Organisations providing technical support to AgriTech initiatives	AgriTechTalk	Technical backstopping of AgriTech initiatives along entire vale chain	Entire value chain depending on programme deliverables	Uganda
Horizontal	Organisations providing technical support to AgriTech initiatives	FrontlineSMS	Technology providers for the mFarmer SMS service platform	Information delivery to farmers	Uganda

Annex 2 List of digital and agricultural policies in the EAC

Digital policies

Data	
Kenya	The Data Protection Bill 2018 (request comments); Privacy and Data Protection Policy 2018 (request comments).
Tanzania	Tanzania does not have a compounded piece of Legislation that governs matters of data protection and privacy. The government intended to enact a personal data protection law that would require all local firms and people to keep their data lawfully. The plan materialised by the Tanzania Data Protection and Privacy Bill of 2014. However, the Bill has not been passed to-date.
Rwanda	National Data Revolution Policy by Ministry of Youth and ICT April 2017.
EAC	–

Intellectual Property Rights	
Kenya	Laws governing Intellectual Property (IP) in Kenya: Constitution of Kenya, 2010; The Seeds and Plant Varieties Act, Cap 326. Anti-Counterfeit Act No.13 of 2008 (revised edition 2016 (2015); Date of commencement is 7 July 2009). The Copyright Act, 2001 (revised edition 2014 (2012)). The Copyright (Amendment) Bill, 2017 (an amendment of The Copyright Act, 2001). Trade Marks Act Chapter 506 (revised edition 2012 (1982); Date of commencement is 1 January 1957). The Industrial Property Act, 2001. No.3 of 2001 Industrial Property Act subsidiary legislation, including Industrial Property Tribunal Rules, 2002 and Industrial Property Regulations, 2002.
Tanzania	The Patents (Registration) Act 1995 version (it supersedes the Patents Act (No. 1 of 1987)). In mainland Tanzania the laws that govern patents are as follows: The Patents (Registration) Act of 1995 (Chapter 217 of the Laws); The Patents Regulations GN. 190 of 1994. In Zanzibar the laws that govern patents are: Patents Decree, Cap 157 (11 of 1930, Cap 9 of 1934, 27 of 1935, S. 5, 11 of 1958) Laws of Zanzibar; Patent Rules (Schedule to Decree No. 11 of 1930) in the Laws of Zanzibar.
Rwanda	Law No.31/2009 of 26/10/2009 on the Protection of Intellectual Property. Rwanda Intellectual Property Policy 2009.
EAC	East African Community Regional Intellectual Property (IP) Policy Aug 07, 2018 (draft) (Regional Stakeholder Workshop on EAC Regional Policy for Intellectual Property (IP) set for 25 September 2018 in Nairobi, Kenya to validate the draft East African Regional Intellectual Property Policy). AC Regional Intellectual Property Policy on the Utilisation of Public Health-Related WTO-TRIPS Flexibilities and the Approximation of National Intellectual Property Legislation 2013.

Science, technology and innovation	
Kenya	Science, Technology and Innovation Act No.28 of 2013 (2014, revised edition 2017); date of commencement is 24 June 2013 (Part VI and VII is 1 October 2014).
Tanzania	The National Science and Technology Policy for Tanzania 1996.
Rwanda	The Republic of Rwanda Policy on Science, Technology and Innovation October 2006.
EAC	Establishment of the East African Science and Technology Commission (EASTECO) in 2007.

Information Communication Technology	
Kenya	The Kenya Communications (Amendment) Act, 2008 (date of Commencement is 2 January 2009; an amendment of The Kenya Communication Act, 1998. The Kenya Information and Communications Act, 1998 (revised edition 2009 (1998)) including various regulations. The Kenya Information and Communications Act, 1998 (revised edition 2011 (2010)). The Kenya Information and Communications (Amendment) Act, 2013 (Date of Commencement is 2 January 2014). National Information & Communications Technology (ICT) Policy June 2016 (draft policy).
Tanzania	Tanzania-ICT-Policy, 2003 (the first formal National ICT Policy). National Information and Communications Technology Policy May 2016. The Access to Information Act, 2016. In 2012, Tanzania adopted the Electronic and Postal Communications Act.
Rwanda	The NICI-2010 Plan – An Integrated ICT-Led Socio-Economic Development Plan for Rwanda 2006-2010. (2) ICT in Education Policy April 2016
EAC	–
e-commerce/ e-transaction/ e-business	
Kenya	The Kenya Communications (Amendment) Act, 2008, and a new part is added as Part VIA which is about electronic transactions. The Information Communications (Electronic Transactions) Regulations 2016 which are seeking comments in 2016, but no official document released.
Tanzania	The Electronic Transactions Act, 2015 (came into force on 1 September 2015).
Rwanda	Law No. 18/2010 of 12/05/2010 relating to electronic messages, electronic signatures and electronic transactions.
EAC	The East African Community Electronic Transactions Bill, 2014.
Digital	
Kenya	n/a
Tanzania	n/a
Rwanda	n/a
EAC	n/a
Technology transfer	
Kenya	Kenya and China launch solar technology transfer and training institute 27 April 2015.
Tanzania	–
Rwanda	1) Alibaba and Rwanda launch electronic trade platform on 3 November 2018. 2) In 2015, C&H Garments, a Chinese garment factory, began operations in Kigali under an arrangement to train and hire the Rwandan workforce.
EAC	–
Other	
Kenya	The Cyber Security and Protection Bill, 2016.
Tanzania	–
Rwanda	–
EAC	–

Agricultural

Food security	
Kenya	1) The Food Security Bill, 2017. 2) National Food and Nutrition Security Policy 2011: according to the WHO, the policy was adopted in 2011 by Ministry of Agriculture. 3) Food, Drugs and Chemical Substances Act Chapter 254 revised edition 2013 (2012). 4) Food, Drugs and Chemical Substances (Food Labelling, Additives and Standards) (Amendment) Regulations, 2012. 5) Meat Control Act Chapter 356, 2012 (1977). 6) Meat Control (Local Slaughterhouse) Regulations, 2010 (Rev. 2012). 7) Meat Control (Local Slaughterhouses) (Licensing) Regulations, 2011 (Rev. 2012). 8) Meat Control (Poultry Meat Inspection) Regulations, 1975 (Rev. 2012). 9) Meat Control (Slaughterhouse) Regulations, 1973 (Rev. 2012). 10) Meat Control (Slaughterhouses) (Licensing) Regulations, 1996 (Rev. 2012). 11) Meat Control (Transport of Meat) Regulations, 1976 (Rev. 2012). 12) The Alcoholic Drinks Control (Amendment) Bill, 2013.
Tanzania	1) The Food Security Act, 1991. 2) The Cereals and Other Produce Act, 2009 (it amends the Food Security Act 1991. 3) The Cereals and Other Produce Regulations, 2011.
Rwanda	1) National Food and Nutrition Policy 2013-2018. 2) Ministerial Order No 012/11.30 of 18/11/2010 on Animal Slaughtering, Meat Inspection.
EAC	1) 5th EAC Development Strategy (2016/17-2020/21) (Narrative Document Final). It includes one strategic intervention about agriculture and food security.

Agriculture	
Kenya	1) Agriculture Act Chapter 318 Revised edition 2012 (1986). 2) Agriculture and Food Authority Act No. 13 of 2013 Revised Edition 2015 (2013). 3) Kenya Agricultural and Livestock Research Act No.17 of 2013 Revised Edition 2015 (2014).
Tanzania	1) Tanzania Agricultural Research Institute Act, 2016. 2) National Agriculture Policy 2013 (Draft). 3) Agricultural and Livestock Policy, 1997.
Rwanda	1) Ministerial Order No 002/11.30 of 13/07/2016 Determining Regulations Governing Agrochemicals. 2) Law No 30.2012 of 01/08/2012 on Governing of Agrochemicals. 3) Ministerial Order No 005/11.30 of 15/02/2013 Determining Fees for Registration of Agrochemicals. 4) Ministerial Order No 001/11.30 of 15/02/2013 Determining the Duties of the Registrar of Agrochemicals. 5) Ministerial Order No 002/11.30 of 15/02/2013 Determining Powers and Responsibilities of an Inspector of Agrochemicals. 6) Ministerial Order No 003/11.30 of 15/2/2013 Determining Confidential Data that are not Recorded and Non-Confidential Data to be Recorded in the Register of Agrochemicals. 7) Ministerial Order No 004/11.30 of 15/02/2013 Determining the Requirements for Obtaining Business License of Agrochemicals. 8) National ICT FOR Rwanda Agriculture (ICT4Rag) Strategy – eTransforming Agriculture in Rwanda 2016-2020. 9) Strategic Plan for Agriculture Transformation 4 (PSTA4) 2018-2024 (presentation in 2017). 10) National Agricultural Policy (Draft) 2004.
EAC	1) Agriculture and Rural Development Policy for the East African Community (November 2006). 2) Agriculture and Rural Development Strategy for the East African Community (2005-2030).

Agro-processing	
Kenya	National Food and Nutrition Security Policy 2011 includes a section on storage and agro-processing.
Tanzania	The Food and Nutrition Policy for Tanzania, 1992 has one part about food processing and preparation.
Rwanda	1) Industrial Master Plan for the Agro-Processing Subsector (2014-2020) by Ministry of Trade and Industry.
EAC	Mentioned in some documents, but no main section about it.
Seeds	
Kenya	1) Seeds and Plant Varieties Act Chapter 326 Revised Edition 2012 (1991). 2) The Seeds and Plant Varieties (Amendment) Bill, 2015. 3) The Seed and Plant Varieties (Variety Evaluation and Release) Regulations, 2016. 3) Seed and Plant Varieties Act (Subsidiary Legislation) Chapter 326. 4) The Seed and Plant Varieties (Amendment) Act, 2011.
Tanzania	1) The Seeds Act, 2003 2) The Seeds Regulations, 2007. 3) The Written Laws (Miscellaneous Amendments) Act, 2010.
Rwanda	1) Ministerial Order No 002/11.30 of 18/08/2010 Determining Regulations on Quality Seeds Production and Control of Seeds Produced and Marketed. 2) Ministerial Order No 003/11.30 of 18/08/2010 Setting Forth Conditions Required for Marketing Quality Seeds. 3) Ministerial Order No 004/11.30 of 18/08/2010 Determining Prices for Services Rendered in Seed Quality Control. 4) Ministerial Order No 005/11.30 of 18/08/2010 Setting Forth Standards for Processing Quality Seeds. 5) National Seed Policy 2007. 6) Law No 005/2016 of 05/04/2016 Governing Seeds and Plant Varieties in Rwanda.
EAC	1) Updating the EAC Seed Legislation and Regulations (1999) 2) Set up a technical committee in 2018 to harmonize corporate seeds laws
Other	
Kenya	1) Plant Protection (Importation of Plants, Plant Products and Regulated Articles) Rules, 2009 (Rev. 2012). 2) National Agricultural Sector Extension Policy 2012.
Tanzania	1) National Five Year Development Plan 2016/17-2020/21. 2) The Food and Nutrition Policy for Tanzania, 1992. 3) The Written Laws (Miscellaneous Amendments) Act, 2010. 4) The Tanzania Food, Drugs and Cosmetics Act, 2003. 5) The Tanzania Food, Drugs and Cosmetics (Control of Food Promotion) Regulations, 2010. 6) The Tanzania Food, Drugs and Cosmetics (Transport of Meat) Regulations, 2006. 7) The Tanzania Food, Drugs and Cosmetics (Treatment and Disposal of Unfit Food) Regulations, 2006. 8) The Tanzania Food, Drugs AND Cosmetics (Fees and Charges) Regulations, 2015. 9) The Tanzania Food, Drugs and Cosmetics (Iodated Salt) Regulations, 2010. 10) The Tanzania Food, Drugs and Cosmetics (Food Fortification) Regulations, 2011.
Rwanda	1) Enabling Self Sufficiency and Competitiveness of Rwanda Rice – Issues and Policy Options 5/7/2010. 2) Law No 16/2016 of 10/05/2016 on Plant Health Protection in Rwanda. 3) National Fertilizer Policy June 2014: Vision.
EAC	1) 5th EAC Development Strategy (2016/17-2020/21) (Narrative Document Final). It includes one strategic intervention about agriculture and food security.

Evidence.
Ideas.
Change.

ODI is an independent, global think tank, working for a sustainable and peaceful world in which every person thrives. We harness the power of evidence and ideas through research and partnership to confront challenges, develop solutions, and create change.

ODI
203 Blackfriars Road
London SE1 8NJ

+44 (0)20 7922 0300
info@odi.org

odi.org
odi.org/facebook
odi.org/twitter