Mainstreaming Digital Approaches for Adaptation in Agriculture in Kenya

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1. Introduction

The Kenyan economy is one of the largest in sub-Saharan Africa. It is backed by a strong agricultural sector, but climate change will increase its vulnerability. Kenya's farming sector directly employs more than 40% of the total population, including around 75% of the rural population, generating about a quarter of the country's gross domestic product (GDP). However, the agricultural sector faces yield gaps and is exposed to climate hazards that contribute to uncertain livelihoods, food insecurity, and persistent poverty among the rural population. Hazards include droughts, floods, growing season reductions, and high growing season temperatures. Additionally, the already strong climate variability makes agricultural production vulnerable. Given the importance of agriculture for Kenya's economy and population, there is a dire need for farming to adapt to climate change and mitigate the effects of these hazards. Effective adaptation can take many forms, but farmers' individual behavior will be central. Better-informed decision-making will play a key role in increasing overall productivity and farmer incomes, and to mitigate climate shocks.

Without adaptation, climate change will affect the food security and livelihoods of millions of Kenyans. Digitally enhanced agriculture involves using modern information and communication technology, especially mobile phones and the Internet, to accumulate, analyze, understand, and disseminate electronic data with the aim of informing effective decision-making along agricultural value chains. For example, digital tools and services can strengthen the agricultural sector's resilience by helping farmers increase productivity, reduce costs and losses, or increase operating profit. Digital adaptation solutions can involve services around agricultural advisory, climate information, input and output market linkages, financial inclusion, or sophisticated 'smart farming' solutions that optimize production using sensors, drones, satellite imagery, artificial intelligence, or shared farm machinery. In the Kenyan context, where most farmers are smallholders, digital technologies for adaptation will likely rely on services accessed via mobile phones such as apps, short message services (SMS), or interactive voice response technology. Digital technologies have the potential to accelerate adaptation processes by addressing the needs of individual farmers in highly scalable service schemes.

Leveraging the potential of digital and data-enabled technologies will be crucial for mainstreaming climate adaptation and resilience in Kenya's agricultural sector and achieving inclusive development. Kenya's thriving digital ecosystem and relatively mature infrastructure offer vast opportunities to develop and deploy innovative and inclusive digital solutions in agriculture. Yet, to date, existing digital services for adaptation in agriculture are used by a minority of Kenyan farmers only. For example, the lack of user-friendly and freely accessible climate information services to anticipate and mitigate extreme weather events is an often-cited challenge for Kenyan smallholders. However, today's near omnipresence of mobile money–which was introduced in Kenya in 2007–has demonstrated that Kenya is ready for digital solutions to be quickly scaled and integrated into virtually all sectors of Kenya's heterogeneous society and economy. But still, low penetration of modern digital devices, scanty coverage by electricity and mobile networks, underdeveloped digital literacy, and gender gaps

concerning the use of digital tools are but some of the challenges affecting the success of digital technologies for adaptation in agriculture initiatives in parts of rural Kenya. Beyond innovative agriculture-oriented services, digital adaptation strategies need to address these challenges with aim of affecting the digital sector at large, and promoting the digital transformation of farming. Given the right environment, digital solutions for adaptation can allow for better-informed agricultural production, marketing, and resource management across all social strata and farming systems.

This project, spearheaded by the African Development Bank (AfDB), the Global Center on Adaptation (GCA), the Alliance of Biodiversity International, and the International Center for Tropical Agriculture (CIAT), explores opportunities and key needs for digital technologies for adaptation implementation within the Horn of Africa Program. The Horn of Africa Program is one of the programs under GCA and AfDB's Africa Adaptation Acceleration Program (AAAP), with the objective of reimagining African developmental institutions, programs, and policies to emphasize adaptation and resilience to climate change. The current project has been conducted in the context of the "Climate Smart Digital Technologies for Agriculture and Food Security" (ClimSmartDigitAg) of the AAAP. The aim is to benefit at least 30 million farmers across 26 countries by 2025 through enhanced, upscaled digital and data-driven adaptation technologies specifically geared toward smallholders and agricultural small and medium-sized enterprises.

The aim of this report is to support digital technologies for adaptation investment decisions in Kenya while highlighting actionable next steps for the design and incorporation of new and better digital technologies within the agricultural sector. The emphasis falls on last-mile delivery of digital technologies for adaptation in agriculture. With attention to local contexts, needs, and potential partnerships, the results from this report are geared toward adaptation practitioners and may also help digital development stakeholders to design and select the most successful investments and interventions. The report starts by exploring the Kenyan regional context to understand population and climatic characteristics, significant agricultural sectors, and relevant climate hazards. It then surveys Kenya's digital landscape to analyze access and use, existing infrastructure, and affordability for relevant technologies to foreground promising digital services for adaptation interventions. With consideration of the obstacles to and advantages for implementation, and short-, medium-, and long-term outcomes, this report seeks to guide investment strategies for digital technologies for adaptation in Kenya. This is followed by the provision of actionable guidance toward attaining essential goals, generating and enabling an environment for digital adaptation solutions and establishing the most viable and demanded tools and services. These include, for instance, early climate warnings, risk assessment and management, advisory services, and building the digital capacity. Finally, this report maps a way forward by synthesizing key digital adaptation actions and recommendations to boost resilience to climate change.

2. Country context

2.1 The economic relevance of agriculture

Kenya, located in East Africa, has a land area of 580,728 km², of which approximately half is agricultural land (CCAFS, 2016). The country's annual GDP is estimated to be around USD 98.8 billion, and a quarter of this is generated by agriculture, forestry, and fishing. The agricultural sector contributes to employment greatly, employing approximately 75% of the rural population and about 40% of the total population (FAO stats, 2021; USAID, 2021a). The export value for agricultural produce is about USD 2.9 billion annually (World Bank data, 2020). However, agricultural production has declined in recent years, impacting the national agricultural GDP growth rate which dropped from 10% in 2010 to 2% in 2017.

2.2 Agricultural production systems

Like most countries in sub-Saharan Africa, agricultural production systems in Kenya are dominated by smallholder subsistence farms, which are normally rainfed. Kenya is divided into seven agro-ecological zones based on precipitation and soil type, which vary in terms of farmer and growing season numbers, and primary crop types. In terms of input usage, an average of 0.25kg/ha of pesticides is applied to fields every year, compared to 2.7kg/ha globally (FAOstats[1]). Regarding fertilizer, instead, its use distributed across croplands is 20.2 kg/ha of nitrogen, 21.1 kg/ha of phosphate, and 5.5 kg/ha of potash (FAOstats[1]). These values are close to the average fertilizer consumption in Sub-Saharan Africa–estimated at 17 kg per hectare of cropland–but far below the global average fertilizer consumption of 135 kg/ha (AGRA, 2019). The main food crops in Kenya are maize, wheat, rice, potatoes, green grams, and beans. Maize is the primary staple food in the country, and 90% of Kenyan farms grow it, while common bean and Irish potato are the most important legume and tuber crops respectively (AFA, 2021). The second largest livestock herd in Africa is in Kenya, ranking 13th in the world in terms of dairy cows. The livestock sector contributes to around 10% of the GDP, and comprises dairy cattle, goats, camels, and beef cattle, small ruminants, non-ruminants, poultry, and emerging livestock species such as quail and rabbits. The livestock population is concentrated in the arid and semi-arid lands towards the East, which cover about 75% of the total land surface (KALRO, 2021).

[1] The numbers reflect the avergae of years 2015-2019

2.3 People and livelihoods

According to the 2019 national census, Kenya has a total population of 47 million people, of which 78% live in rural areas (KNBS, 2019). 37% of the total population lives below the US$ 1.90/day poverty line, which is closely related with the prevalence of undernourished people (25%) and the prevalence of children underweight and wasting (11.2% and 4.2% respectively) (World Bank data, 2014). These numbers are reflected in the Global Food Security Index, where the country has a score of 46.8 out of 100, meaning that its performance is moderate and there is still room for improvement. One of the main reasons for this is the high prevalence of undernourishment (The Economist, 2021). In terms of education and infrastructure, instead, the country is rapidly improving, with the literacy rate among youth standing at 88%. Access to electricity has been rapidly increasing, and 56% of the population is already connected, while 46% of the rural population has electricity (World Bank, 2020). This expansion has been mainly catalyzed by the Kenyan government's rural electrification programme.

3. Climate vulnerability and resilience

Kenya is highly vulnerable to climate change and variability. The Notre Dame Global Adaptation Initiative Country Index Rank sees Kenya 147th out of 177 countries, with a score of 39.1. Kenya scores 0.518 on vulnerability and 0.300, making it the 38th most vulnerable country, and the 39th least prepared. Therefore, there is a great need for investment and innovations to improve readiness and resolute action. By 2030, losses related to climate variability and extreme events are predicted to be up to 2.6% of the annual GDP (USAID, 2018). Droughts alone would cost an estimated 8% of the GDP every five years. The recurrent annual burden caused by these climatic extremities will lead to large economic losses of up to $0.5 billion per year, further suppressing economic development (GoK, 2015). The cumulative impacts of climate change over the next two to three decades have the potential to reverse much of the progress made towards the attainment of the Millennium Development Goals (MDGs) and Vision 2030. This section will examine climate change vulnerabilities and resilience concerning cereals and livestock value chain commodities, the most pressing challenges for Kenya. Additionally, it will focus on the projected impact of climate change on these major value chain commodities or their sensitivity to climate change-related risks and hazards such as diseases, crop failure, and the destruction of assets on farm, post-harvest, and at the market level.

Kenya has a diverse climate, with variable annual rains. Some parts of the coastal and highland areas receive annual averages up to 2.000 mm. Yet, 80% of the land mass is classified as arid and semi-arid, receiving less than 500 mm of rainfall per year. Temperatures range from an average of 18°C in high elevation areas like Nairobi, to 26°C in coastal areas such as Mombasa. Hazards stemming from Kenya's changing climate include high and extreme climate variability, heat stress, droughts, floods, growing season reductions, high growing season temperatures, or a combination of the latter. Its geographic location also makes the country prone to cyclical droughts and floods, with climate change expected to make such climate driven events increase in intensity and frequency (GoK, 2015). Arid and semi-arid areas are especially prone to extreme events such as droughts and floods (Marigi, 2017), and periodic droughts occur in Kenya rather frequently. Moderate drought events have been recorded on average every three to four years, and major droughts affect the country every ten years on average. Prolonged droughts, instead, have become more common since 2000 (GoK, 2015). The most drought-susceptible areas are counties on the Eastern, Northeastern, and Coastal regions, and parts of Rift Valley. January, February, and June to September are the most common drought months, especially in the northern parts of the country. For example, the recent 2020 drought severely affected both the arid and semi-arid counties. The level of food security in these regions was reportedly one of the lowest in the last 15 years, affecting around 1.8 million people, and currently a drought is exposing more than 2 million people to food insecurity (UNOCHA, 2020; NDMA, 2021).

Floods mostly occur in the Budalangi, Nyando, Homabay, and Tana River Counties in the lower Tana River catchment. Major cities such as Nairobi and Mombasa, and Northeastern parts of the country, are also prone to flash floods (KMD, 2021a). Highland areas, instead, are prone to landslides and mudslides which manifest during the rainy season. These areas are characterized by steep slopes, and include counties such as Murang'a and the Embu highlands. The number of landslides is reported to be increasing as forested lands are converted to agriculture, resulting in looser soils and fewer trees to slow the flow of water downslopes (Parry. et al, 2012). Kenya's extreme floods have been observed to be triggered by severe thunderstorms, tropical cyclones, and heavy rainfall over many consecutive days. The El Niño Southern Oscillation, Madden Julian oscillations, and other phenomena have been observed to exacerbate the flood situation in the country. For example, at the end of 2015, heavy rainfall driven by the El Niño (KMD, 2021a) killed at least 112 people and displaced over 100,000. The most recent flooding event, instead, took place in spring 2021, displacing thousands of people.

Another allegedly climate-related extreme has been the desert's locust invasion, which affected the country between 2019 and 2020, with large swarms spreading across fourteen Kenyan counties, influenced by both wind and rainfall within the region (KMD, 2021a). The locust invasion and other climate-related shocks contributed to a slow recovery from the effects of previous droughts, especially for the most vulnerable communities in the pastoral counties (NDMA, 2020).

The average temperature has increased by 0.34°C from 1985 to 2015, with the greatest increases manifesting in the months of March to May in arid and semi-arid regions. Projections show increases in mean annual temperature between 1 °C and 1.5 °C by 2030 (World Bank & CIAT, 2015). By 2050, average temperatures are projected to increase from 1.2°C to 2.2°C, with the greatest warming happening in the west (USAID, 2018). The number of hot days and nights will increase. Hot days are projected to be between 19% to 45%. Hot nights, instead, are expected to increase quickly, and to occur on 45% to 75% of nights by 2050. Increased heat and extreme heat conditions will result in significant implications for human and animal health, agriculture, and ecosystems (GoK, 2015; World Bank, 2020).

Although there is little change in overall average annual precipitation, since the 1970s, long rains show reduced rainfall in Central and Southern Kenya, with possible increases in the northern parts of the country (USAID, 2018). Analysis by GoK with data starting in 1960 concur that northern areas of the country have become wetter, southern areas drier, and there also seems to be an increase in the proportion of heavy rainfall events (GoK, 2015). Rainfall projections show a likely increase in average rainfall (projections range from -3 to +28%) from October to May, and a decrease in the duration of dry spells, albeit increased in severity (-2 to +27%) (USAID, 2018). Changes in rainfall distribution and more frequent extreme events are projected to result in more frequent water shortages (World Bank & CIAT, 2015).

To identify the likelihood of future climate hazards and their potential impacts in Kenya, we mapped them out for the 2050 period under a business-as-usual emission trajectory (Figure 1). Our projections for 2050 show that 73% of the land used for agriculture in Kenya is under threat from a combination of high to extreme climate variability, heat stress, and droughts, and another 18% is because of a combination of high to extreme climate variability and droughts (Figure 1.a). Climate hazards will hinder the agricultural production of cereals and livestock on over 40 million ha of land (Figure 1d). This would have substantial implications for the rural populations whose livelihoods depend on agriculture. The consequences for small-scale farmers include changes in water availability for crop and livestock production, as well as livestock losses, crop failures, and lower incomes. Other impacts of climate variability include greater incidence and prevalence of crop pests and diseases. On the other hand, in some places this might lead to opportunities for crop diversification and intensification (Rippke, et al, 2016). Finally, more than 15 million rural people and USD 1.9 billion in crop and livestock value are exposed to climate hazards (Figure 1b and c).

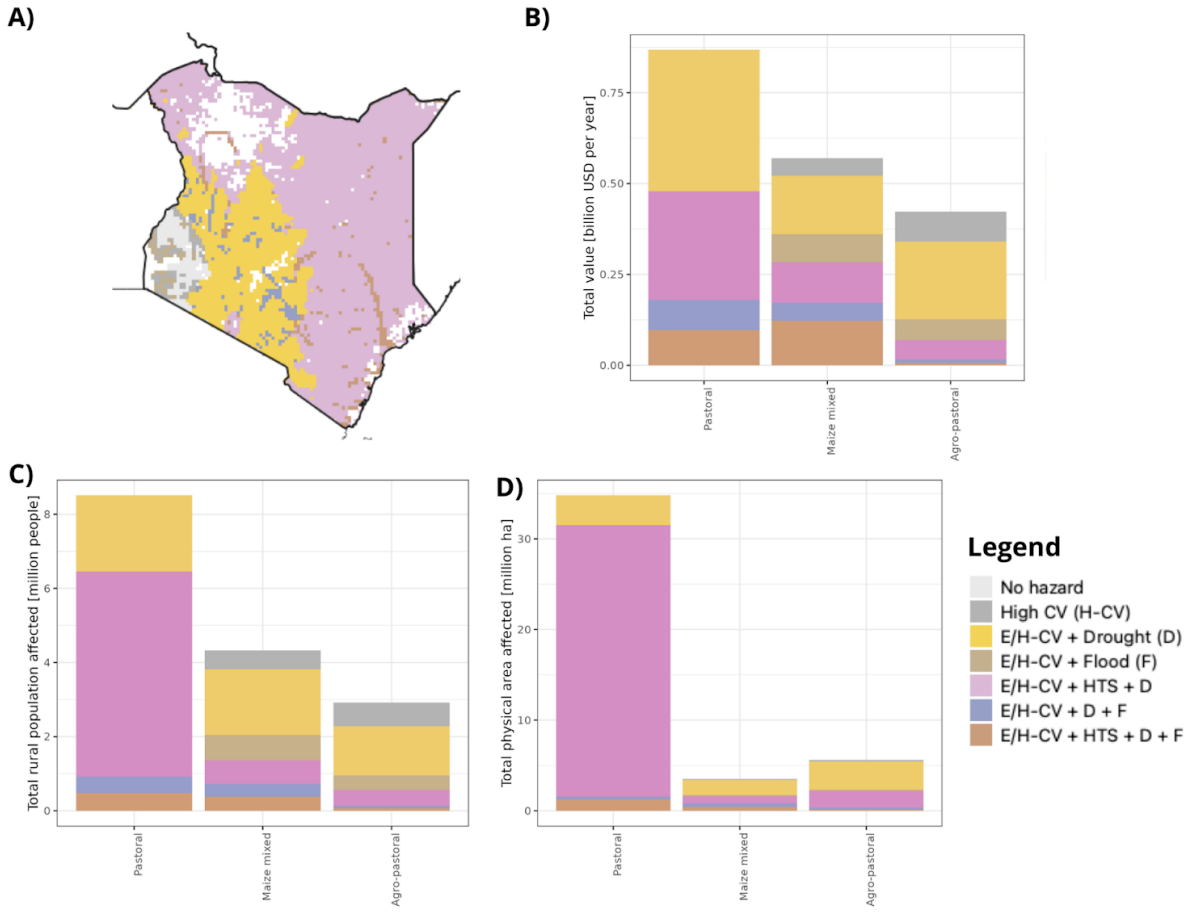

Figure 1: The distribution of predominant climate hazards in Kenya. All hazards are calculated for the 2050 period under Representative Concentration Pathway 8.5. Hazard categories: High climate variability (H-CV), Extreme to high Climate variability (E/H-CV), Heat Stress (HTS), Drought (D), Flood (F). A map of the geographic distribution of hazards (A). Exposure of total crop and livestock production value (B), of the rural population (C), and of the total physical area (D) to climate hazards for several farming systems in the Horn of Africa region by 2050 (RCP 8.5). Note that the value of crop production is based on the 42 crops and crop categories of the MapSPAM 2017 dataset (IFPRI, 2019). The production value is given per year.

3.1 Climate vulnerability across cereal and livestock value chains

Without proper adaptation strategies, climate change will lead to serious consequences for key activities along the agricultural value chain at all stages, including input supply, on-farm production, post-harvest processing, and output markets. These impacts are exacerbated by relatively small farm sizes, land degradation, and deforestation, which characterize the agricultural production systems in the country. For this section, a selection of value chains was chosen for a deeper analysis of how climate change affects them.

Maize: Maize production systems are prevalent across Kenya and are highly vulnerable to climate change. Annual losses by 2050 are estimated to be between USD $100 and 200 million (Herrrero, 2010). Moreover, yields are expected to decrease at a rate of 0.07 tons/ha/decade, reaching losses between 12% and 23% by 2055, while food prices will increase between 75% and 90% by then (FICCF, 2013; Mumo, Yu, & Ke, 2018). Long, dry spells will affect maize production directly. In fact, the crop is very sensitive to water deficits from flowering to beginning of grain filling (Omoyo, et al., 2015). Earlier in 2021, below-average precipitation amounts in the planning season forced several farmers to re-plant, causing irreversible damage in plants and reducing production by 8% (FAO, GIEWS, 2021). Flooding has also a negative impact on production, leading to crop yield losses, soil erosion, waterlogging, and the leaching of soil nutrients and fertilizers. The viability of seeds is also reduced as the seeds rot in the soil. Excessive rainfall–especially during the harvest–can bring about rotting. In addition, the inadequate drying of maize under wet conditions heightens the chances of aflatoxin contamination. In 2020, the maize farms of Baringo County were flooded, and crops were lost to the floodwaters (KMD, 2020). Maize can also be damaged by temperatures over 35^0C, which are increasingly common in lowland regions (USAID, 2018). To counter the adverse effects of climate change, it is necessary to climate-proof agricultural crops through adaptation strategies, such as developing drought-tolerant, heat-resistant, and early maturing maize varieties (Omoyo et al., 2015).

Livestock: In arid and semi-arid regions, pastoralism is the dominant production system, hosting approximately 70% of the national livestock herd (Chaudhury et al., 2020). However, it is characterized by unsustainable practices such as overstocking and open grazing. Additionally, the projected climatic trends are negatively influencing production. Pastoral communities in Kenya are already acutely affected: high temperatures are increasing heat stress, as well as pest and disease incidence in livestock. The decrease on annual rainfall leads to feed and water scarcity, impacting the quality and availability of pasture (USAID, 2018). In northern Turkana County, increased competition over grazing lands and water has already heightened the likelihood of conflict and insecurity (HRW, 2015). These are further exacerbated by poor physical and social infrastructure, resource conflicts, and low literacy levels, which further reduce the people's adaptive capacity to droughts (KMD, 2021a). In recent months, livestock trekking distances from grazing fields to watering points have increased in several counties. In August 2021, the distances were 25% to 55% longer than average (FAO, 2021). Grazing resources in most northern pastoral areas and central and southern agro-pastoral areas have been severely affected

by two consecutive poor rainy seasons since October 2020. As of September 2021, drought conditions were reported in several counties, with particular concern for Marsabit County in the northwest, and Mandera, Garissa, Isiolo, and Wajir Counties in the northeast (FAO, 2021).

Animal health is also affected by both extremely high or low temperatures and by the emergence and re-emergence of infectious diseases, some of them transmitted by vectors that are highly dependent on climatic conditions. In 2011, the livestock sector lost approximately around 6 billion USD because of drought (GoK, 2013). When disaggregated, 0.5 billion were lost due to costs from veterinary care, water, feed, and production decline, and 5.7 billion due to animal deaths. Climate change also reduces productivity. In fact, in mid 2021, milk production was 25% to 45% below average (FAO, 2021). The prices of livestock have declined by 10% to 30% due to rain shortage in the last two seasons. This is affecting particularly areas hit by prolonged droughts, such as northwestern Turkana, Samburu and Marsabit counties, and northeastern Garissa and Wajir counties (FAO, 2021).

3.2 Factors that determine vulnerabilities and impacts to climate change

The majority of Kenya's population is dependent on agriculture, and generally has low adaptive capacity to withstand the negative impacts of climate change. In addition to the biophysical factors mentioned in the previous section, other factors play a role including poor infrastructure, weak institutional mechanisms, and lack of financial resources (GoK, 2015). There are several other socio-economic factors that leave the Kenyan population vulnerable to climate change, and adaptation efforts should take them into account, as they could represent a hindrance. Poverty is an example of this. In the Rift Valley, Eastern, and Nyanza regions, 40-70% of the population lives on less than USD 1.90 per day, and these areas lack essential infrastructure for adaptation to climate change. For example, efforts to expand irrigation are hampered by poverty and low technical capacity (Chaudhury et al., 2020; Ministry of foreign affairs Netherlands, 2018; HRW, 2015). Furthermore, population increase and the scarcity of non-degraded potential agricultural land leads to land fragmentation. This also hampers the economy of scale to invest in new technology or use part of the land to try out new varieties of practices.

Smallholder, low-input, and rain-fed agriculture in the arid and semiarid lowlands are more vulnerable because of their dependence on climate-sensitive and natural resource-based economic activities. Over 75% of the total agricultural output is produced on these small-scale farms, making the system especially vulnerable to climate shocks (GoK, 2015). Additionally, weak land administration and management due to a lack of comprehensive national policies has caused land fragmentation and disparities in ownership, resulting in inadequate conservation measures. The lack of clarity on ownership of resources, combined with resource degradation due to climate change, has caused conflicts in various parts of the country in recent years (Ministry of Foreign Affairs Netherlands, 2018).

Access to timely information is also key. Producers lack relevant weather forecast data and information that would assist them in reducing their losses and diversifying with more suitable crops, such as drought tolerant crops during the dry periods and slow-maturing varieties when conditions are wetter than normal (Marigi, 2017). Using digital tools for the production and dissemination of climate information can enhance it's reach and use. However, the gap in (digital) illiteracy rates exacerbate the lack of access to climate information systems. Higher literacy and capacity building around using digital technologies could provide the public with a pathway for creating knowledge about climate change and an awareness of possible adaptation solutions.

Additionally, the severity of the impacts of climate change are not evenly distributed over the population. Evidence from 8 African countries including Kenya, shows that climate change is correlated with increased migration of the youth, and this is especially strong for agricultural communities in drought prone areas (Bezu et. al., 2020). This effect is also stronger for men than for women due to fewer recourses and cultural constraints. On the other hand an important consideration regarding youth in agriculture is that this group has had a relatively better education and is more likely to use digital tools than older generations. When targeting digital interventions for adaptation it is therefore important to consider how the youth fits in, whether this is at the farm, extension, in the digital workforce or in agri-entrepeneurship levels.

Women are another group that are often disproportionately affected by the effects of climate change. Women manage over 40% of smallholder farms and provide up to 80% of labor for crop production in Kenya (UNDP, 2012), but have a lower adaptive capacity to tackle negative climate change impacts because of less access to information, markets, mobility, alternative income sources, land ownership, access to credit and means of decision-making (Diiro et. al., 2018). Therefore women's empowerment should be a key consideration when thinking about implementing digital services for adaptation as this not only contributes to reducing the gender gap in agricultural productivity, but also to a greater scale and impact of adaptation strategies.

4. Climatic adaptation needs

4.1 Existing climate change adaptation strategies

Integrating climate risks and actions into development planning–both across sectors and from the national to the local level–is essential for making it more resilient to climate change. Kenya is committed to climate change adaptation and mitigation through the development and enforcement of national policies and frameworks in collaboration with the United Nations Framework Convention on Climate Change (UNFCC). These include, for example, the National Forest Policy (2014), the National Climate Finance Policy (2016), the National Climate Change Framework Policy (2016), the Kenya Climate Smart Agriculture Strategy (KCSAS) 2017 – 2026, the National Climate Change Action Plan (NCCAP) 2018-2022), and the Kenya Climate Smart Agriculture Implementation Framework (2018-2027). Certain counties have downscaled some of these policies to guide their specific development plans. For instance, the Kitui Climate Change Fund seeks to finance climate change resilience and mainstreaming programming and investment; Wajir county has a climate change act since 2016; Makueni county has enacted the County Climate Change Fund Regulations; and Turkana County has implemented the County Climate Change Policy. Furthermore, Isiolo, Wajir, Makueni, and Garissa counties have put in place the Climate Information Services Plans. Still, many counties have not taken action yet. It is therefore crucial for them to localize policies based on their climate change needs.

In support of adaptation and mitigation efforts, Kenya published its second National Communication in 2015, and submitted its Updated Nationally Determined Contribution to the UNFCC in 2020. This helps improve the country's ability to prepare for and respond to natural disasters and increase resilience. Currently, Kenya is working to meet the goals and adhere to its climate change strategies by investing in actions such as afforestation and reforestation, geothermal energy production and other clean energy development, climate smart agriculture, and drought management (Ministry of Environment and Natural Resources 2016). Regarding the agricultural sector specifically, on- and off-farm adaptation measures are being currently implemented.

Some of the successfully implemented on-farm adaptation practices include intercropping–which has an adoption rate of 60% in Western and Eastern Kenya–and mulching, which is mainly practiced in tea growing areas, which also has an adoption rate of 60% (World Bank & CIAT, 2015). Other practices are terracing, contour bunds, construction of dykes, changing planting dates, and enterprise diversification (Ochieng et. al., 2016). The effects of drought can also be reduced by cultivating drought-resistant crops and fodder such as cassava, millet, pigeon peas, green grams, cowpeas, and brachiaria, especially in semi-arid areas (CIAT, 2015). Other practices include planting early maturing crop varieties, staggered planting, and improved pastures management (CIAT, 2015). A recent survey in the Central Highlands showed that most farmers were adopting one or several types of adaptation strategies, with the most common used practices including crop rotation (60%), terraces (66%) and fertilizer plus manure (71%) (Mairura et. al., 2021). They also found a link between climate change

perceptions and the use of certain adaptation strategies; for example, almost all farmers who perceived climate variability implemented crop rotation practices, while no significant correlation was found between climate perception and nutrient management strategies. They found that adoption and the choice of a particular strategy was also related to the level of knowledge farmers had about the adaptation strategy, as well as their access to credit.

To address the problem of increasing water scarcity, farmers are involved in its conservation and distribution, aiming to minimize drought impacts and improve agricultural production in dry regions. Water harvesting is a crucial adaptation measure in Kenya. This is done through several methods. Surface water harvesting includes the construction of earth dams, embankment dams, water pans, and sand dams; groundwater harvesting involves boreholes, shallow wells, and subsurface dams; rooftop rainwater harvesting, instead, is done by collecting excessive rainfall using water tanks. The availability of water has the positive effect of increasing productivity and reducing farmer-herder conflicts over access to water (MoALFC, 2021). Water is also crucial to reduce wildlife-human conflicts, which happen when animals invade farmlands in search of water. Irrigation is also a key measure that can address water scarcity. An example of its use is for rice cultivation in the Eastern parts of the country (MoALF, 2016). However, in general, uptake is low due to the high cost associated with the development and maintenance of irrigation infrastructures. Out of the 6.4 million households practicing agriculture in the country, only 369,679 households are practicing irrigation (KNBS, 2019).

Timely, early warning systems are one of the off-farm adaptation strategies in use in the country. Early Warning Systems enable farmers to know when and where to plant, and when to move with the livestock in the face of expected climatic shocks. This information is generated by Kenya's meteorological department (KMD) and the National Drought Management Authority (NDMA) and is promoted through websites, pamphlets, SMS, WhatsApp messages, and monthly bulletins, and is disseminated in vernacular radio stations (CARE, 2018).

Adaptation strategies around post-harvest and market access include incorporating traditional knowledge and farmers groups. Traditional knowledge can add value to their produce and limit the increased post-harvest losses resulting from climate change and variability. For instance, farmers can process raw milk into ghee. Also, some farmers in Kenya are organized into farmer groups and cooperatives, increasing their capacity to benefit from economies of scale by reducing the costs of inputs, storage, and transport. Moreover, cooperatives and farmer groups play a critical role in the production, processing, and marketing of major agricultural commodities and services. Incorporating adaptation strategies at these levels will reduce the risks and bring adaptation technologies to scale and more rapidly.

4.2 Potential adaptation strategies

Even though there are several ongoing adaptation strategies in the country, there is ample opportunity for more innovative and transformative measures to assist stakeholders across multiple value chains. For example, it is critical to increase water availability to vulnerable farmers, both in terms of quality as well as quantity. Some potential adaptation strategies include bringing irrigation facilities and surface water harvesting to scale. Similarly, pasture availability is a constraint in the pastoral systems. Farmers can be sensitized to practice the conservation of fodder and the production forage that is drought-, pest-, and disease-tolerant. It is also important to upscale disease surveillance, health management, breeding, and control of endemic diseases to ensure high-quality livestock products in the country. Similarly, farmers can be trained to correct and balance fertilizer application. Given the highly degraded soils of Kenya, it's crucial for farmers to adopt a combination of organic and inorganic fertilizers to improve soil quality and fertility. Organic fertilizers may not only improve soil quality, but may also contribute to climate protection by increasing carbon sequestration in agricultural ecosystems (Zhang et al., 2016)

To counter the detrimental impacts of soil erosion, sustainable land management practices can be promoted. These include: terracing; contour bunds; drainage canals; agroforestry; and perennial crops. These practices will increase soil carbon, improve the management of soil organic matter, and rehabilitate the already degraded lands. Additionally, intercropping nitrogen-fixing perennial woody species and trees with annual crops increases soil fertility, produces biomass, and reduces soil erosion. This practice also promotes carbon sequestration and redistributes carbon to deeper soil layers (KMT, 2019). Furthermore, the low adoption of conservation agriculture in the country needs to be tackled.

The use of new protocols and technologies concerned with credit acquisition will help farmers invest more in agricultural activities and consequently increase the adoption of tools that will safeguard farmers against the uncertainties arising with climate change. Another important use of digital tools in agriculture to aid smallholder farmers is for insurance. Several pilots have emerged worldwide testing different strategies, from using satellite images to registered local weather events, such as hail and lightning, to access the location and severity of the impact this has had on crops. Another way of doing so is through an app that uses pictures to process damage to crops, such as the picture-based crop insurance app[2] that is currently being tested and used in Kenya. One issue that remains is that without ways of controlling for the using agronomic best practices, or investments possibilities in technologies like irrigation in drought prone areas, it has not easy for insurance companies to come to a sustainable business model. However, artificial intelligence and machine learning, in combination with easy to use apps, remote sensing and digital agricultural advisories, can lead to insurance companies mainstreaming the use and affordability of insurances and with that, reaching smallholder farmers at scale.

[2] https://www.ifpri.org/project/PBInsurance

5. Digital readiness

5.1 Stakeholder network around digital technologies for adaptation

Nairobi is the biggest digital innovation hub in Eastern Africa, hosting many of the most promising tech companies in the continent. There are several organizations working in the field of digital technologies that can be used for climate adaptation in agriculture in Kenya. This growth has been fostered by a friendly regulatory and policy environment. Innovation hubs have also facilitated the process by providing mentorship and business support to entrepreneurs. As a result, in 2020, 95 services were recorded in the field of agriculture (GSMA, 2020). These services include advisory, financial, procurement, e-commerce, and smart farming services, as well as several technologies, including adaptation strategies.

There are also several public organizations working in the field of digital technologies for adaptation: the Kenyan Agriculture and Livestock Organization (KARLO) is directly involved in researching and developing solutions, often collaborating closely with entrepreneurs and startups. Kenya also has its own space agency (Kenyan Space Agency, KSA) which focuses, on agriculture, disaster management, and resource management among other things. It has a satellite imagery analysis portal, and it is working on developing an Open Data Cube for anyone who wants to access the images (Kenyan Space Agency, 2021).

For a long time, the Kenya Meteorological Department (KMD) has been the only national institution providing climate information services. However, in recent years, collaborative, private sector–driven climate information service initiatives have been established. Furthermore, several international development agencies, NGOs, and private tech companies have been increasingly supporting efforts to provide climate information services (CIS) in the country. Examples include ICPAC, FAO, ACMAD, FEWSNET, AGRA, ILRI, ICRISAT, RCMRD, KALRO, Mercy Corps AgriFin, Esoko, aWhere, ACRE Africa, Upande, GCAP, GeoEnvigro, and AirtelKilimo (ICPAC, 2021, see stakeholder list in the annex).

5.2 Coproduction

The Kenya Meteorological department (KMD) provides the agricultural sector with weather and climate information. The KMD collects data through its own climate observation stations and collaborations with other institutions and volunteer observers. It maintains a large meteorological infrastructure comprising 40 synoptic stations, automatic weather stations, airport weather observing systems, and satellite receiving stations, often operated in collaboration with other international climate centers and volunteer observers (Meteo.Go.Ke, 2021). However, the data from the Automatic Weather Stations is not yet fully integrated into meteorological applications, as the quality of their datasets are yet to be

known (Muita, et al., 2021). These meteorological services are devolved, and each county has a coordinator in charge of disseminating climate information services.

In 2020, KALRO launched the Kenya Agriculture Observatory Platform (KAOP), which provides real-time access to ward-level, seven-day weather forecasts including rainfall and temperature, all critically important inputs to inform farm operations. This platform has been recently updated through a partnership between KALRO and aWhere, in which KALRO gained use of aWhere's 6,787 virtual weather stations in Kenya to provide advanced weather data and analytics.

Early Warning Systems are also extremely relevant. Drought monitoring and risk management systems are key, especially because, as opposed to floods, the impact is less visible and more difficult to quantify in economic terms. To prevent drought damage, the National Drought Management Authority manages the Drought Early Warning System (DEWS) which operates at the national level. The system releases drought Early Warning bulletins for different regions in the country based on real time data, (NDMA, 2021). There is also the Predictive Livestock Early Warning System (PLEWS), which has been developed by several national and international agencies and aims to reduce livestock losses. PLEWS uses normalized difference vegetation index data and models it against edible vegetation based on high resolution satellite imagery and ground truthing, surface water availability, and past data (Matere, et al., 2020). The tool is still in its pilot phase, but it holds great potential, and it is planned to scale up to other countries in the Horn of Africa.

Although there is a good data collection network, capacity to translate weather and climate inputs into user-friendly products generally remains low. Producers and other relevant stakeholders are therefore largely unaware of existing climate information services. To overcome this issue, KMD is in the process of establishing the National Framework for Climate Services in Kenya, which will provide an institutional mechanism for coordinating, facilitating, and strengthening collaboration to improve co-production, delivery, and use of climate services for decision making. An example of existing co-production approaches for climate products are the Country Climate Outlook Forums, which use Participatory Scenario Planning to produce downscaled seasonal forecasts and advisory services. The system is already being used by the KMD to develop forecasts for the planning season (ICPAC, 2021). Moreover, the KMD together with IGAD is establishing the National Framework for Climate Services in Kenya (NFCS), an institutional mechanism to coordinate, facilitate and strengthen collaboration among national institutions. The aim is to improve the co-production, tailoring, delivery, and use of science-based climate predictions and services for decision-making. The process is still ongoing, and so far stakeholder consultations and workshops have been conducted (KMD, 2021b).

5.3 Translation

Telecommunications infrastructure

Almost 100% of the population has second generation (2G) network coverage, and 96% has 3G coverage. However, 4G reaches only 65% of the population, and fifth generation (5G) hasn't arrived in the country yet (GSMA, 2021). Mobile Network Operators (MNOs) include Safaricom PLC, Airtel Networks Ltd, Telkom Kenya Ltd, Jamii Telecommunications Limited, and Equitel, with 64.2%, 26.9%, 6.2%, 6.2%, and 2.3% market shares respectively. Although SIM penetration is very high (114 per 100 habitants), the rate of unique subscribers is significantly lower (57.5%) and mobile phone ownership is even lower (49%) (ITU data from 2019, GSMA, 2021). This indicates that some people share the same phone but use different SIMs, while others have multiple SIM cards and other SIM cards are still registered but not in active use anymore. However, in 2019, only 23% of the population uses the Internet, and this is just a slight increase from 17% in 2014. (ITU data). This low rate can partially be explained by costs, since Internet data remains expensive, as 100MB are 44% of the monthly GDP per capita (GSMA, 2021). There are about 11 million social media users in Kenya, and this number has rapidly increased by 25% between 2020 and 2021 (Kemp, 2021). The number of social media users in Kenya was equivalent to 20.2% of the total population. However, when it comes to social media users, there is an important gender gap of 56% (GSMA, 2021), most likely connected with affordability, privacy, and security concerns.

Regarding global indexes such as the Network Readiness Index, Kenya can be found quite high in the scale, ranking 82 out of 182. The score is especially high for governance and regulations (Portulans Institute, 2021). In the Digital Readiness Index, instead, Kenya was a bit lower, ranking 104 out of 141. The country has especially good scores for human capital (skilled labor force to support digital innovation), startup environment, and ease of doing business. However, concerning technology adoption (which includes internet adoption) and basic needs (for example access to clean water or energy) the scores are quite low (CISCO, 2019). Despite improvement over recent years, Kenya remains in the lower 30% of countries globally in the ICT Development Index.

Kenya is a reference for mobile money in the region. Mobile money has been a game changer in Kenya, and due to its widespread use–even in rural areas–it can now be used for many digital financial services. Between April and June 2021, total active registered mobile money subscriptions rose by 4.7% to stand at 34.7 million, which could be attributed to increased uptake of digital payments to contain the spread of COVID-19.

Access to climate and weather data

In Kenya, weather and climate information services are communicated using different channels such as mass media, print media, and the Internet. A report from 2016 breaks down the most used media: bulletin/newspaper (52%), radio (45%), intermediaries (41%), SMS (34%), Website (21%), and interactive voice response (IVR-10%) (World Bank Group, 2016a). Regarding radio, the KMD works with several local community radio stations to disseminate climate information to smallholder farmers and other vulnerable communities. However, it has been found that most farmers did not find the climatic information received through radios and local admin useful for operational decisions. All studies point to the fact that there is a mismatch between information provided and user needs, as well as an inability to interpret weather data and translate it into decisions, leading to decreased use of the information (Onyango, 2014, Masieyi, et al., 2021, Cherotich, 2012). On the other hand, intermediaries include extension services, which are the only channel that delivers not just information on climatic hazards but also support services for adaptation. KALRO and the MoALF, for example, have a network of extension officers who receive information from KMD. However, the MoALF extension services are still under resourced. In some instances, KMD provides early warning and climate information specific to flood prone areas, such as some parts of Western Kenya.

Climate services tailored to end users

There is a need to translate weather and climate inputs into user-specific products that aid climate adaptation decision making. The KMD is already working in this direction and has piloted a project on the western part of the country (which is the most populated area) to provide localized weather services. The project has included capacity building of staff and improvement in the dissemination of information. To reach the population, weather forecasts have been integrated into other existing information systems (such as farm inputs or advisory supplies emails or SMS services) (KMD, 2019). KMD also works closely with CABI Plantwise programme to generate pest risk information which is used as an early warning system and measure to ensure that farmers are aware of pest prone areas.

5.4 Transfer

Digital information transfer models

TV: “Shamba Shape Up” aims to give farmers the tools they need to improve their farms (shambas). Each episode focuses on one farmer and their farm, reaching around 7 million Kenyans weekly (Shamba Shape Up, 2021).

Radio: It is the most popular medium and is widely used for the transfer of agricultural information. Farm Radio has a strong presence in the country, potentially reaching 24 million listeners. There are also many radio stations that disseminate climate-related information. Some examples include, Nganyi

RANET, Kangema RANET, Bulala RANET, Wajir Community Radio, Pamoja Radio, Baliti FM, DARAJA Initiative under the WISER programme, and the ACREI project in Taita Taveta, amongst other initiatives.

Interactive voice response (IVR), SMS, and Unstructured Supplementary Service Data (USSD)

- *Arifu* is a digital content and interactive, personalized, and free learning platform. It works through an omnichannel chatbot, allowing both smart and feature phone users to learn via SMS, WhatsApp, and Facebook Messenger.
- *iCow* is a digital platform that aims to reduce cow mortality rates and educate farmers on proper agricultural practices. Farmers can easily register through USSD, where they are asked to provide specific information about their cows. Once the farmer has provided all the needed information the service sends them tailored SMS' with tips about breeding, animal nutrition, and milk production. The service works as a calendar for cows. There is also an app version.

Digital platforms and apps:

- *Safaricom DigiFarm* is Safaricom's integrated, mobile platform of digital services for farmers. Accessible on a basic feature phone, it brings together multiple input and service providers onto one platform. Farmers can order inputs, engage in learning, access input credit, harvest cash loans and insurance. connect with buyers, obtain soil testing, and aggregate their products.
- *MyAnga* offers early warning and SMS alerts for pastoralists. It also provides weather forecasts and advice about weather and forage conditions (CTA, 2019).

Digital payments:

- *Mpesa* is an electronic mobile money service that allows users to store, send, and receive money on their mobile phone. It is also possible to withdraw cash by visiting an agent (typically in a corner shop) or transfer it to others from your phone. This makes it a quick, safe, and simple way to make payments and handle money. The service is integrated in the SIM card from Safaricom, and users can access it via USSD.
- *e-voucher program* rolled out by the Kenyan Cereal Enhancement Program (KCEP) supplies farm inputs at affordable prices. Through the e-voucher platform, farmers can open bank accounts and budget their resources across different e-wallets. The vouchers can be used to buy pre-prepared input packages of seeds, equipment, and consumables from selected suppliers (KNA, 2020).

Insurance:

Acre Africa, although not an insurance company directly, functions as a service provider working with local insurers and other stakeholders *to* provide index insurance products, including weather, soil moisture, vegetation, and multi-peril coverage for crops and livestock. This is done through risk assessments, product development and risk monitoring.

5.5 Use

Driven by increasing mobile phone usage, several AgriTech companies and private sector organizations are spearheading digital agriculture technologies to develop and disseminate climate and information services to enable adaptive agriculture. Yet, many existing solutions have not achieved mainstream use, and a lot of farmers remain unaware of their existence and benefits. Reasons hindering adoption are high technology costs, low digital literacy, limited infrastructure access, and weak enabling policy environment (Osiemo, et al., 2021). The urban-rural gap on ICT usage is especially noticeable, and can be explained by the lack of infrastructure and electricity, rather than human factors such as literacy and income. This divide is more pronounced than the gender gap (the rural-urban gap is 69%, while the gender gap is 31%), and is especially noticeable when looking at Internet users. In fact, most Internet nonusers are women (58%) living in rural areas (84%) (Nyambura Ndung'u, Lewis, & Mothobi, 2019). Women also encounter other disqualifying factors. For example, they are less likely to purchase their own smartphone due to affordability, and they are less aware of the Internet. This makes women less likely to use digital agricultural apps, increasing the gender gap in agricultural productivity. A great opportunity to overcome this is to design services specifically for women, applying an inclusive lens.

Another factor to consider when it comes to digital technologies is cyber security. The Communications Authority of Kenya reported 10.2 million cyber threats in 2018 across all sectors. Capacity building for developers and end-users, together with further support of the public and private sector, is essential to ensure further benefits to the already thriving Kenyan digital ecosystem. Initial studies done by the AfBD, FAO, World Bank, and CIAT to assess Kenya's digital ecosystem and prioritization of digital technology uses found that some of the biggest constraints producers face include a lack of decision support, knowledge access, and mechanization. Therefore, investing in weather stations, data analytics, and machine learning offer significant promise in terms of addressing these issues.

Table1. Summary of key issues by stage in the information value chain including indicative relevant stakeholders in each stage.

Stage	Stakeholders	Key Challenges
Production	Service providers: meteorological services institutes such as GPCs, RCCs and NMHSs, observers, modelers, forecasters, product developers, research institutes, climate science institutes, community level traditional forecasters	• Capacity and motivation to change and develop new ways of working • Infrastructure for weather and climate data collection • Accuracy of forecasting • Minimal effort to obtain feedback from users; where feedback is sought, the process is not regular or systematic • Limited coordination across government ministries with NMHS and other actors • Complexity of forecasts vs. user • Limited understanding • Cost and limited financial resources • Limited coordination across government ministries and with NMHS, civil society and the private sector
Translate and transfer	Sectorial experts and ministerial departments (e.g., Agriculture, DRM, Water, Health, Energy), communicators and boundary organizations (e.g., Broadcast Media, ICTs, vernacular radio, Telecom companies, Agricultural Extension Officers, NGOs, CBOs), enablers and partners from government, public and private institutions, Non-Governmental Organizations (NGOs), Community-Based Organizations (CBOs) and Faith or Farmer-Based Organizations (FBOs)	• Weather & climate services technical expertise • Mainstreaming climate services into policy, planning, and decision making • Agricultural extension agencies are not generally involved in the preparation or dissemination of agrometeorological bulletins • Most agrometeorological bulletins target government agencies, NGOs, and regional and international organizations, only about 20% target farmers and the general public
Use	People i.e., farmers, pastoralists, fishermen, forest, water and natural resource users and managers, climate sensitive sector departments, relevant specialized institutions, planning officials, decision- and policymakers, relevant ministries and authorities, public and private media, NGOs, CBOs, small enterprises &organizations that benefit from access to and the use of climate information	• Owning a mobile phone • Mobile network coverage • Internet coverage • Internet use & Affordability • Electricity (in rural areas) • Educational level/Literacy level • Digital literacy • Poor quality assurance • Use of mobile payments

6. Use of digital technologies in climate-smart agriculture

This section gives a selective overview of digital services currently available to and used by many farmers in Kenya. In general, the development of these solutions has been driven by entrepreneurialism, while government interventions have focused on providing an enabling environment, including investments into digital infrastructure. Over recent years, Kenya has seen the emergence of digital tools that take advantage of the widespread mobile phone use and increased uptake of mobile money. These instruments formalize agricultural value chains and deliver efficiencies for agricultural stakeholders, including smallholder farmers, crop aggregators, crop buyers, and agribusinesses. The most common digital agriculture services in Kenya include advisories (24%), financial inclusion (20%), market linkages (18%), agriculture intelligence (16%), and supply chain management (8%) (Osiemo et al, 2021). A 2019 report by the Global System for Mobile Communications (GSMA) subdivides digital agriculture tools available in Kenya into three categories: market linkage tools, direct-to-farmer hubs, and last-mile digital tools. *Market linkage tools* allow crop producers and buyers to connect through mobile-based online platforms, such as Twiga Foods. *Direct-to-farmer hubs* are centralized online, mobile-based hubs that offer a range of agricultural information, inputs, and loans. The hubs provide platforms through which third-party agricultural service providers can offer services directly to farmers, while buyers can place orders to farmers. An example of a direct-to-farmer hub is DigiFarm for Consumer, an integrated mobile platform that offers farmers "one-stop" access to services such as discounted inputs, advice on input use, crops and animal information, and financing. *Last-mile digital tools* provide solutions that digitize transactions (procurement, payment, receipts) and streamline communication. They additionally create digital profiles for farmers and enable track-and-trace. An example of this is Virtual City.

Some of the main services are listed below to exemplify existing efforts to apply digital climate-smart agriculture technologies to adapt to adverse climate impacts and ensure food security.

WeFarm is an SMS-based, free-of-charge platform where over 2.4 million farmers worldwide connect to solve problems, share ideas, and spread innovation. WeFarm aims to keep the service for farmers free of charge while relying on crowsourced funding and bringing in revenue through their marketplace and by selling data about found agricultural trends. WeFarm's service employs the latest machine learning technology to provide tailored, crowd-sourced information to help farmers increase yields, gain insight into pricing, tackle the effects of climate change, source the best quality of seeds, fertilizers, and loans, and diversify their agricultural interests.

iShamba is a call center for farmers and send localized weather information weekly to almost half a million farmers. Users can SMS their questions or call and speak to an expert for instant help. Agricultural experts oversee requests. Once farmers have signed up, they also receive agri-tips on crop and livestock, market prices, and weather updates.

myAnga is an agri-weather information app created for pastoralists that provides them access to accurate weather data, allowing them to enhance their response to harsh weather conditions and climate variability. The app provides daily weather observations from the past seven days, daily weather forecasts for the next seven days, rainfall distribution over the past 30 days, expected moisture conditions, and expected drought conditions. They currently have a reach of 500 herders in two counties, but aims to reach more than 300.000 pastoralists in Kenya over the next five years.

Acre Africa is a service provider linking over 1 million farmers in Kenya, Tanzania, and Rwanda with local insurers, facilitating investment in their farms. The offered products vary from crop, livestock, and index insurance to shield farmers against unpredictable weather conditions. The ACRE Africa team undertakes risk assessment, product development and risk monitoring to facilitate smallholder access to crop and livestock insurance products. With customized agriculture microinsurance products, farmers can confidently invest in quality inputs, increase productivity, and access agricultural loans. In addition, the team has developed insurance products to cover a variety of crops against weather risks like drought, storms, flood and erratic rains, as well as other production risks.

Apollo Agriculture, serving over 40,000 farmers since inception, bundles everything a farmer needs: financing, farm inputs, advice, insurance, and market access when possible. The company builds credit profiles for its small-scale farmers using machine learning models. It does so by verifying the identity of farmers and taking satellite coordinates of their fields. The obtained data is then used to build automated digital processes for each step in a farmer's lifecycle—from customer acquisition to training to collecting payments. These data collection and analysis procedures and credit building processes guide the company in making scalable lending and credit decisions for farmers. Additionally, the company helps them access increasing levels of their investment over time.

Kuza Biashara serving over 3,500 agri-entrepreneurs and 500,000 farmers is a mobile micro-learning platform offering youth, women, and micro-entrepreneurs from informal communities the opportunity to learn, connect, and grow on their terms and convenience. The platform includes packages on digital extension.

National Livestock Market Information System (NLMIS) provides livestock market price and volume information on a near real-time basis using mobile technology across Kenya. The system works by collecting price and volume data from designated markets and conveying it to the NLMIS server in Nairobi using SMS-enabled cell phones and a data coding system. This data is then available to all interested parties via SMS query, on the server, or through the Internet portal. The information assists pastoralists and other stakeholders in critical risk management decision-making and market linkages.

There are also several digital technologies and/or platforms where there might not be a direct connection to climate adaptation, but are still worth highlighting as these technologies when bundled with other services can serve as climate adaptation technologies in agriculture. For example, integrating climate information services or advisories climate smart agriculture with the highlighted technologies below can enhance the impact of these services separately for adaptation purposes.

DigiFarm is a free mobile-based platform offered by Safaricom to over 1.3 million registered smallholder farmers. It offers them a marketplace to access products and services from financial institutions, agro-input providers, and other value-added services. The service is accessible through USSD, and once the user has registered, it allows them to access loans through their M-Pesa account and discounted inputs from selected depots. Users also have access to learning content.

iProcure is an agricultural supply chain platform. It connects product suppliers and retailers, providing procurement, distribution services, business intelligence, and data-driven stock management across supply chains. Through this model, product suppliers can benefit from the retailers' network and reach the remotest locations.

Twiga Foods is a mobile-based supply platform for Africa's retail outlets, kiosks, and market stalls. It provides a business-to-business supply platform to access distribution into the millions of small and medium-sized vendors in African urban markets. The platform connects farmers to vendors, reducing the number of intermediary steps, lowering the product's final price, and increasing the farmers'

income. The platform claims that over 100,000 customers use its services across Kenya while delivering more than 600 metric tons of produce to 10,000+ retailers daily.

Hello Tractor tackles the lack of mechanization, connecting tractor owners with smallholder farmers. The start-up provides Internet-of-Things-enabled (IoT) digital solutions that allow farmers to optimize their productivity. It is the largest marketplace for agricultural equipment in Africa. To date, Hello Tractor has mechanized over 500,000 farmers in 15 countries and has more than 3,000 tractors on its marketplace. The company can also provide a pre-screened pipeline of borrowers in need of asset financing, accompanied by the assurance that financed tractors are pre-booked on its marketplace and able to earn revenue to pay-off financing.

Virtual City is a solutions provider specialized in developing and deploying mobile-based retail and financial solutions for agribusinesses. Their work revolves around supply automation, mainly across tea, coffee, dairy, horticulture, and grain verticals, aiming to create efficiency, visibility, and transparency for all key stakeholders. They provide digital tools that accelerate financial inclusion for farmers and de-risk investment decisions for financial service providers. An example of one of their solutions is an electronic weigh-scale that, combined with a device connected to the Internet, allows to keep track of the products that farmers bring to their cooperatives for accurate payments.

7. Assessment of the potential of digital technologies for adaptation

On November 30th, 2021, a national stakeholder consultation workshop was held in Nairobi to assess, validate, and prioritize a potential long list of digital adaptation technologies identified through a comprehensive literature review. Several key stakeholders from a range of sectors participated in the workshop. These included public, private, local, and international research centers, as well as academia, NGOs, and international development partners. The workshop provided an opportunity to assess and validate the current viability and future potential of key digital adaptation technologies appropriate for Kenya's national context. The long list digital adaptation technologies were subdivided into nine digital service categories (Porciello et al., 2021): digital financial services, water and irrigation, livestock knowledge and information, weather and climate, value chain management, extension and pest management, general agronomy and community supported agriculture (CSA), seed and fertilizer, and precision agronomy and soils. Existing and potential new digital adaptation technologies were assessed and validated through a stakeholder lens based on practical experience and knowledge in designing, adopting, and scaling digital adaptation technologies in the agricultural sector.

A digital technologies for adaptation support readiness index was developed to inform digital adaptation priorities using the Progress, Policy, Potential, Efficiency, Equity, and Environment (PPP/EEE) method to shortlist the digital adaptation technologies based on their respective service category. Based on this, stakeholders scored the shortlisted digital services according to a set of criteria. These included existing digital infrastructure, current technology maturity, ICT policies, economic prospects, technology drivers, adoption barriers, effects on equality and the environment, and future impacts of the respective tools. The results are depicted in a heatmap in figure 2.

The PPP/EEE analysis results indicated that several digital adaptation technologies are already in small-scale adoption stages, except for digital finance services and water and irrigation, which are already in the scaling-up stage. Precision agronomy, seeds, and fertilizers stand behind the rest of digital services as these are still in the research and development phase. The current uptake is low for most technologies, reaching only 0-40% of the targeted users. As a result, profitability is also low. This is because the existing ecosystem offers a wide range of services, while simultaneously being highly fragmented—which can be very confusing for farmers. Additionally, a lack of focus on developing sustainable business models and user readiness for technology design led to lower uptake and profitability.

An enabling environment with supportive policies and programs is being created for most digital adaptation services, especially for general agronomy and CSA practices. However, there is still room for improvement, most notably for policies concerning weather and climate, seeds and fertilizer, and precision agronomy and soils technologies. There is also room for direct and indirect government support for all categories. Some examples are indirect programs that focus on overcoming barriers related to smartphone access, data sharing, and digital literacy while providing actionable information to users and developing frameworks for transparent and safe data sharing.

Most categories are seeing some degree of investment. However, in most cases, this is not enough to ensure the successful and widespread use of these technologies, except for digital adaptation services under the category of water and irrigation. At the same time, the expected ten-year return on investment for each digital adaptation service is moderate to high, except for seed and fertilizer and precision agronomy and soils. The adaptation technologies with the highest expected profitability are digital

financial services, water and irrigation, extension and pest management, and general agronomy and CSA. This shows that the expected return on investment would not happen without substantially increasing current investments, and there would be a gap due to the loss of profits on both sides of the demand and supply chain.

The efficiency, equity, and environmental outcomes are especially favorable for solutions in the areas of water and irrigation, and weather and climate. Nevertheless, it is expected that all digital adaptation technologies will increase the efficiency of farmers and pastoralists by reducing labor and promoting the efficient use of input and resources. All technologies have received a favorable score in terms of equity due to their high potential to increase fairness while aligning with different demographics, gender, and agro-ecological contexts. However, the livestock knowledge and information and value chain management categories have scored low. To overcome the associated potential shortcomings, implementers must pay particular attention to them. For example, reaching small-scale (nomadic) pastoralists is not as straightforward and profitable as reaching larger-scale livestock producers that use digital technologies. This could considerably increase the gap between the two, and interventions must ensure that digital adaptation technologies will also serve small-scale producers to enhance equity. Moreover, most of these technologies' categories are also expected to positively impact the environment and natural resources. Still, digital financial services, seeds and fertilizers, and precision agronomy and soils could have a negative impact if not managed with the appropriate knowledge.

Figure 2: PPP Assessment of Digital Adaptation Technologies per Service Category

Analysis of the results from the stakeholder consultation workshop in Kenya where key stakeholders from a range of sectors including the public and private sectors scored the current technology maturity, the enabling environment and future impacts of the digital adaptation technologies.

8. Enabling digital for adaptation of agriculture

The digital transformation of Kenya's agricultural sector provides farmers and pastoralists with new ways to understand, manage, and transform their practices and activities. This becomes crucial in light of climate change. Over the past decades, there has been significant progress in the digital transformation of Kenya. The government has backed this transition, creating an enabling environment that promotes the provision and use of ICT services, including several supportive laws, strategies, and policies that promote digital, innovative solutions. As a result, Kenya ranks high in the Global Innovations Index (GII), and it is the third most innovative country in Africa (GSMA, 2018), featuring one of Africa's most advanced digital ecosystems (World Bank, 2017). Nevertheless, the benefits of this recent development are not distributed equally, and women and minority groups still face multiple challenges in terms of digital accessibility. This section will address several enabling factors and critical barriers that need to be tackled to ensure greater use of digital adaptation services.

8.1 Key enablers of digital solutions for adaptation in Kenya

Digital infrastructure

ICT infrastructure plays a crucial role in catalyzing and supporting digital technologies for adaptation in agriculture. The growing network coverage and the increased quality of mobile data are key enablers. At a continental scale, Kenya's digital infrastructure is relatively well-developed. Over the last two decades, the Kenyan government has invested in fiber-optic cables and broadband network stations, leading to significant improvements in digital service availability, including in rural areas. Multiple undersea cable providers serve Kenya's high-speed Internet connectivity. These include the East African Submarine Cable System (EASSy), The East African Marine System (TEAMS), the Lower Indian Ocean Network 2 (Lion II), and Seacom cables. Five major mobile network providers compete on the Kenyan market, which Safaricom and Airtel currently dominate. This has led to an overall satisfaction rate of 96 % for Kenyans using a third-generation (3G) network and more than half of the adult population owning a mobile SIM subscription (GSMA Mobile Connectivity Index, online). Currently, there are about 33 million feature phones and 26 million smartphones subscribed (CA, 2021). These promising statistics are partially aided by public efforts towards rural electrification, which currently covers a minimum of 62 % of the rural population—the highest rate in the Horn of Africa region (World Bank, 2022). However, network connectivity remains scanty in many rural areas despite general network availability. Moreover, with an average of USD 2.25/GB, the cost of mobile data is relatively high in Kenya, reducing the affordability of digital services that require Internet access (cable.co.uk, 2021). Policy interventions that lower the cost of data packages, such as public subsidies, could help make digital adaptation solutions more inclusive.

Sectorial policies and strategies

National policies and government strategies provide an enabling environment for digital adaptation technologies, including a robust institutional and legal framework supporting the growth of the agricultural sector. For instance, the Data Protection Act (2019) and the Agricultural Sector Transformation and Growth Strategy (ASTGS, 2019) provide regulatory guidelines for digital initiatives.

The Data Protection Act, which has been primarily modeled on the European General Data Protection Regulation, ratifies a right already present in the Kenyan constitution: the right to privacy. The legislation focuses on protecting users' right to privacy and data security concerning the processing of personal data on a national or transnational level. In the ASTGS, the government has committed to "establish[ing] a digitally enabled extension program led by ~3,000 county-based youth extension agents" with the aim of "supplement[ing] the current estimated workforce of 4,000-4,500 extension officers." The ASTGS also foresees strong cooperation with private companies and NGOs in the field of digitally enabled agricultural extension and encourages the use of digital decision-support tools that have been proven to work outside of Kenya, such as the 'Rice Doctor[3].'

The liberalization of the policy framework around digital communication has attracted many players to join the industry. In 2008, the Communications Authority of Kenya (CA) introduced the Unified Licensing Framework (ULF) based on unified technology neutrality licensing. The ULF permits any form of communications infrastructure to be used to provide any type of communications service that an operator or service provider is capable of offering. This regulation effectively abolished multiple licensing regimes where services were grouped based on technology. ULF also simplifies licensing procedures, new application development, internet penetration, and infrastructure investment. As a result, there has been an increase in infrastructural development and entrepreneurial activity, partly driven by international companies.

Yet, while the sector's strategies and policies articulate the government's position on digital technologies for adaptation, specific laws and regulations regarding digital agriculture have also been introduced in recent years. In addition to the Kenya Information and Communication Act (2008), the National ICT policy (2016) is the primary policy document that defines the agricultural sector's digital development environment. However, outstanding concerns around third-party liability and appropriate consent from farmers and other primary data providers are yet to be addressed.

In 2010, the Kenyan government released multiple regulations to govern the ICT sector. Among these, the Fair Competition and Equality of Treatment Regulations promote competition, equal treatment, and protection against abuse of market powers or other anti-competitive practices essential to developing a vibrant digital technologies for adaptation sector. In addition, universal access and service regulation seek to provide a regulatory framework for achieving equitable access to digital services in Kenya. Established in 2010 and governed by the Communications Authority of Kenya (CA), the 'Universal Access Fund' collects a mandatory fee of 1% gross revenue from all commercial communications licensees operating in Kenya. In accordance with the ULF Framework, the fund aims to support widespread access to quality ICT services through targeted investments into infrastructure, innovative service development, and capacity-building projects.

Proliferation of ICT-based initiatives

Nairobi is a major hub for providers of digital adaptation solutions across sub-Saharan Africa, including both established players and many start-ups. Farmers in Kenya have many established digital services at their disposal. The Digital Agri Hub currently lists 67 functional solutions in Kenya, which is more than in any other country worldwide, and GSMA listed 95 solutions in the agricultural sector (GSMA, 2020). In addition to providing a favorable policy environment, the Kenyan government has co-invested into multiple tech hubs such as iHub and NaiLab in Nairobi, where start-ups can work and connect with investors and partners (World Bank, 2016b). A relatively well-developed infrastructure and mobile phone penetration in farming communities, along with a pool of trained IT talent, have led to many initiatives focused on developing and piloting new services in collaboration with Kenyan farmers. While many of these initiatives offer real benefits for their users, public efforts in coordinating different solutions are limited—for example, regarding content clearance for coherent messaging at farmers. To

[3] http://www.knowledgebank.irri.org/decision-tools/rice-doctor

date, there are no official certification schemes that would allow public staff—including extension officers—to promote the uptake of certain digital services by farmers. The Kenyan government's supportive yet hands-off approach to private sector-driven innovation has yielded the establishment of many promising digital adaptation services. However, many small start-ups struggle to move from the application development stage to full-fledged businesses. Currently, scaling the most promising projects depends on garnering public support and reaching out to marginal communities. This could happen through direct credit provision, tax exemptions, subsidies, or public-private partnerships between start-ups working on digital climate smart solutions and public offices like KALRO. Together with the World Bank, the Kenyan government is already improving this situation through the One Million Farmer Platform. The platform aims to bring innovations to scale and connect them to different counties. These types of initiatives can be combined with a farmer registry, which would facilitate all registered farmers to access a comprehensive set of governmental services, including vouchers, insurances, and advice.

8.2 Key barriers for digital adaptation solutions in Kenya

Gendered access to digital technology

Overall, Kenya's rural population is relatively well covered by digital infrastructure and end-user devices, including smartphones. However, women are currently less likely to benefit from digital adaptation solutions. Mobile phone ownership is lower among women than men (figures vary by source but lie between 5 and 20 %). Women are also more likely to own a feature phone rather than an internet-enabled phone or smartphone, meaning that the divide in accessing advanced digital solutions is greater than the divide in mobile connectivity (Alozie & Akpang-Obong, 2017; GSMA, 2019; Osiemo et al., 2021; USAID, 2021b). In addition, gender gaps in schooling, literacy, and numeracy make it harder for women farmers to access, understand, and use the information provided in digital adaptation solutions, especially if these solutions are text-based and use English rather than a local language. Furthermore, women are more risk-averse to technology use than men, and less likely to trust digital information systems (Stumpf et al., 2020). On average, learning styles also differ between genders, where women are usually more systematic in learning how to use new tools, while men have a stronger preference for tinkering—i.e., learning-by-doing (Stumpf et al., 2020). This has implications for the design of digital adaptation solutions, as decisions on user experience or content design can affect the engagement of women and men differently. Human-centered design (HCD) processes for new digital adaptation solutions can help to ensure that digital services fit women's digital capacities, abilities, and preferences. In HCD, digital developers actively engage a diverse range of farmers—especially women and marginalized social groups—in defining the features of the digital adaptation solution (Müller et al., 2022; Steinke et al., 2022). Kenyan authorities such as CA or KALRO can mainstream gender considerations in licensing, investors can emphasize the need for gender balance among users, and publicly supported hubs and start-up programs (e.g., Startup Savanna, startupsavanna.com) could offer methodological support in implementing successful HCD processes.

Gaps in awareness and digital literacy

Because the agricultural extension sector in Kenya is highly fragmented and privatized, no centrally controlled organization reaches out to farmers. In addition, the strong cultural and biophysical diversity makes it challenging for digital initiatives— particularly small start-ups—to create awareness among farmers and scale their user base. As a result, farmers in Kenya now have numerous digital solutions at their disposal but are insufficiently aware of potentially useful digital adaptation options. Low levels of digital literacy among the farming population reinforce this problem (Osiemo et al., 2021; Coggins et

al., 2022). While many farmers are familiar with making phone calls, using WhatsApp, and navigating Facebook, the wider Internet and other mobile apps are much less common among the rural population.

Limited "service discoverability" has been identified as a key barrier to Kenyan farmers' adoption of digital solutions (Kieti et al., 2022). More centralized coordination—for example, by CA—and public support in the promotion of prioritized services may help. However, Kenya still lacks an easily accessible, central platform or database that can provide interested farmers with an overview of functional digital adaptation options. A quality-certified, continuously maintained, one-stop digital marketplace where farmers can identify and try out digital adaptation solutions could simultaneously address low trust and low awareness issues. It has been suggested that public or private investments into building and maintaining an inclusive, user-friendly "aggregator platform for digital services in agriculture" would pay off via increased uptake of digital solutions by farmers (Kieti et al., 2021). An aggregator platform could be implemented as a website, app, or an IVR- or USSD-based recommendation (and registration) system. However, setting up this system will require significant collaboration from the diverse private and public sector stakeholders in the digital technologies for adaptation space.

9. Recommendations

9.1 Enhancing the enabling environment

By now, numerous private sector initiatives have successfully demonstrated both technical feasibility and the existence of farmer demand for diverse digital adaptation solutions. This includes various agro-advisory, marketing and procurement, and machinery rental services, that either directly or indirectly (as a partner company) bring adaptation practices to producers and other stakeholders. While services such as Twiga Foods, WeFarm, or Hello Tractor have already gained large user bases across the country, many other initiatives remain operative at a small scale and will struggle to become financially sustainable without donor or government support. Kenya can now reap the benefits of providing a stimulating environment start-ups working on digital technologies for adaptation and should identify the most promising digital services that align with user needs and government and donor agendas in agricultural development. Market dynamics and venture capital drive current digital development in Kenya. Therefore, poor smallholder farmers' uptake of these digital tools will continue to be slow without interventions from government or non-profit organizations programs, as they are not the main target group of these commercial initiatives. The AfDB and GCA program AAAP's pillar ClimSmartDigitAg is a key example of such a program that aims to mainstream the use of digital climate smart technologies. Another example is that through public calls for tenders, **Kenyan authorities and their partners may now identify priority solutions to support their scaling through public-private partnerships**. Consultations among CA, KALRO, the Ministry of Agriculture, and county governments will help define which extant digital technologies for adaptation providers best suit the development goals. Public-private partnerships around digital technologies for adaptation could then take multiple forms, including direct commissioning of services by the Ministry of Agriculture—which is subject to robust evaluation of impacts on farmers' livelihoods—or providing privileges, such as subsidies, tax exemptions, or free access to meteorological or agronomic data held by KMD or KALRO. The ultimate goal of these partnerships is to enable promising digital solutions for adaptation to grow their user bases, become financially sustainable through business models, and increase their impacts on the Kenyan farming sector.

Kenya's agricultural sector provides multiple public goods, including food, employment, and landscape management. Given the sector's vulnerability to upcoming climate change, investments by the Kenyan government and international donors into digital technologies for adaptation seem warranted but can be unreliable. **Digital adaptation strategies should prioritize self-sustaining business models in the interest of a permanent, sustainable transformation.** With growing numbers of users, many digital solutions for adaptation can offer their services at minimal costs per user. 'Freemium' schemes are also feasible. Here, subsistence farmers are provided with free services (or at a symbolic cost), while funds are drawn from commercial users such as larger farms or other value chain actors. Developing farmer registries across individual services with government-verified farmer data will be helpful to design fair pricing schemes.

The fragmentation of the existing digital solutions for adaptation sector and a lack of coordination and cooperation among its stakeholders currently create barriers to successful, large-scale digital adaptation solutions. In addition, the fragmentation causes transaction costs and creates confusion among potential users. A more centralized, hands-on approach might enable farmers to efficiently identify trustworthy solutions that meet their needs. One recommendation is creating **an overview platform that allows farmers, extension officers, and other stakeholders involved in agricultural value chains to identify suitable digital services**. An essential quality criterion will be **official accreditation and continuous quality control by public authorities or national research organizations**. This should

ensure consistency and complementarity in the information and advice provided across different digital adaptation services.

Eventually, the **fragmentation of digital adaptation solutions and resulting transaction costs can be reduced by promoting vertical integration and bundling of services along and across value chains.** Rather than engaging with multiple digital services—each with a unique user interface—farmers should eventually be able to access a wide variety of services such as personal credit, input procurement, climate information, agro-advice, and output marketing within a single bundled 'master' service. Such integration will likely require significant efforts by public institutions (i.e., facilitation, financial incentives). Establishing a dedicated government body in charge of governing and promoting digital technologies for adaptation might help. Such an organization could be staffed by CA, the Ministry of Agriculture, or both and would need a clear political mandate to be accepted by other industry stakeholders as a driving agent of digital adaptation solutions in Kenya. It should operate within a clear legal framework and ensure innovation, quality, compliance, and accountability within the sector.

Despite an overall positive trend in the past, resource-poor farmers in Kenya continue to be disproportionately underserved by electricity and mobile data network. The digital divide between urban and rural areas, men and women, and large and small farms persists across most of the country. **Directing public or private investments into last-mile connectivity** will be a major priority for enabling inclusive digital development. Past experiences have shown that the growing availability of high-quality mobile networks can stimulate farmers, including women, to invest in internet-enabled devices that run digital adaptation services. However, the relatively high costs of mobile data have been another factor discouraging farmers from using existing digital adaptation solutions. Since access to data can now be considered a vital input to modern farming, policymakers may consider policy action to lower consumer prices for mobile data. Worldwide, mobile data is particularly cheap where market competition is strong and government regulation of the telecommunications sector is weak. Market competition among mobile service providers could be governed by more selective licensing. Digital literacy programs—for example, in public schools—could also help strengthen demand for and future use of digital adaptation solutions. As the general population becomes more aware of data privacy concerns, ensuring that sound policies are in place will protect producers and maintain trust in digital tools for adaptation in the future.

9.2 Recommendations by solution space

In addition to the recommendations around an enabling environment in the previous section, table 2 depicts specific recommendations by solution space. These solution spaces were determined through the stakeholder consultation workshop as discussed in chapter 6. The recommendations listed below are the result of a combination of the literature review and the stakeholder consultation process. It is important to note that although these recommendations take both the supply and demand side into account, further fine-tuning of these digital technologies needs to be done in close consultation with the end-users. This should be an ongoing process to ensure that the digital technologies grow with the needs and skills end users have.

The recommendations in table 2 are around both the technical and the implementation side of digital technologies, and together can be seen as a package for their solution space. In some cases these can be implemented successively, but in most cases are important to be implemented as parallel processes. There are many technological overlaps between the different solution spaces and individual solutions. As capacity increases in one area, this will likely result in increased capacity in support of other solutions and solution spaces. Although these recommendations take both the supply and demand side into account, further fine-tuning of these digital technologies needs to be done in close consultation with the end-users. This should be an ongoing process to ensure that the digital

technologies grow with the needs and skills of end-users. Table 2 also links these recomendations with the Climate Smart Digital Technologies for Agriculture and Food Security pillar in the GCA and AfDB Africa Adaptation Acceleration Program. Finally, important ideas and considerations are listed under the column 'Actionable Insights'.

Table 2: Recommendations per solution space

SOLUTION SPACE	LINK TO THE AAAP PROGRAM	RECCOMENDATIONS	ACTIONABLE INSIGHTS
Weather & Climate	Digital upskilling	**Further system and capacity development** in working with real-time early warning systems based on satellite data for floods, drought, and pests, in partnerships with international (science) organizations.	• Many of the capacities and technical systems associated with these recommendations are already established in national programs, but can further benefit from partnerships with international research centers and universities. • Early warning systems should be coupled with advice on how to prepare for the imminent hazard and should be presented to users in their local languages in order to maximize uptake. • Multi-pronged strategies are required to reach the broadest possible user base, including focus on improving digital literacy, increased access to technology, and multi-channel information flows (e.g., radio, text messages, infomediaries), especially targeting women producers and minority groups.
	Climate services	Development and continuous upgrading of the **back-end and front-end system** for real-time early warnings.	
	Climate services	Improvement of **digital information services**, including hazard mapping and short-term seasonal forecasts.	
	Climate services	**Promoting the use and understanding** of early warning systems amongst the producers and pastoralist communities through community outreach and training programs.	
Water & Irrigation	Climate smart agriculture	Development of **forecasting models for watershed management and soil moisture** estimation through satellite to inform smart maps for informing producers -directly or indirectly- on water availability and sustainable land and water management practices.	• Partnerships that involve government, the private sector, and the research community from the outset will accelerate innovation, adoption and uptake of viable and locally relevant technologies. • Setting up partnerships to bundle the use of simple irrigations system and water management practices with financial services can help provide loans for initial investments and give incentives to farmers to start these practices. • Use existing digital communication channels, such as Facebook and YouTube.
	Climate smart agriculture	Providing information to farmers, for example through **videos, radio or IVR**, on how to use (simple) irrigation systems and general water management.	
Precision agronomy & Soils	Climate smart agriculture	**Simple to use advisory systems** can bridge advanced science with the extension agents in the short term.	• Integrate adaptation measures into precision agronomy and soil management digital technologies to ensure adaptation practices become embedded and mainstreamed from the start. • Improvement of the current policy environment around storage, access and management is necessary.
	Climate smart agriculture	The use of **drones** would help detect and monitor upcoming pest & diseases that arise due to climate change.	

SOLUTION SPACE	LINK TO THE AAAP PROGRAM	RECCOMENDATIONS	ACTIONABLE INSIGHTS
Seeds & Fertilizer	 Climate smart inputs	Analysis and giving information about **what varieties work best under changing circumstances** due to climate change, coupled with information on how to optimally use fertilizer and other agronomic practices will help with adaptation needs awareness.	• Partnership development with local and international scientific organizations for climate smart and location-specific recommendations.
Value Chain Management	 Climate smart agriculture	Develop and provide more **information about post-harvest options** -especially about processing and value addition- to farmers based on forecasting of the impacts of climate hazards.	• Partnership development with local and international scientific organizations will ensure that forecasting of climate hazard impacts can be included along the value chain.
	 Climate proof market access	Establish **traceability systems** and mechanisms for crops and livestock management, integrating them along the whole value chain.	
Livestock Knowledge & Information	 Climate services	Development and integration of **smart maps and pastoralist grazing routes** with climatic information, early warning risk analysis and mapping for livestock and nomadic animal movement and distribution.	• Clear and context specific privacy policies and information use guidelines are required to foster the development of trusted farmer registries and information sharing protocols that foster innovation and protect farmer privacy. • Providing digital literacy training for extension agents is crucial. The established, extensive network of local extension agents can be a lever for boosting the digital literacy of farmers and promoting the use of digital services.
	 Climate proof market access	**Digitalize the livestock industry market information system**, including post-slaughter and quality checks for markets (using global market standards), and the conversion of livestock data collection into digital format.	
	 Climate smart agriculture	Provision of **advisory** to pastoralists and farmers on climate-smart practices via mobile SMS, IVRS, radio, and apps.	
	 Climate proof market access	Establish **traceability systems** and mechanisms for livestock management, integrating them along the whole value chain.	
	 Digital upskilling	**Promoting the use of digital tools** for livestock management through community outreach and training programs for pastoralists and broader stakeholder training.	

SOLUTION SPACE	LINK TO THE AAAP PROGRAM	RECCOMENDATIONS	ACTIONABLE INSIGHTS
General extension	 Digital financial services	Continue the development of a national **e-registry** of pastoralists and farmers.	• Clear and context specific privacy policies and information use guidelines are required to foster the development of trusted farmer registries and information sharing protocols that foster innovation and protect farmer privacy. • The established, extensive network of local extension agents can be a lever for boosting the digital literacy of farmers and promoting the use of digital services. This will likely first require digital literacy training for extension agents. • Digital information services should collect feedback from users, creating a two-way information flow. • Hybrid extension models that integrate digital tools with a human touch (e.g. plant doctors, digital village advisors) will provide greater access to less literate users and marginalized communities.
	 Climate smart agriculture	Provision of advisory to farmers on **climate-smart land management practices via mobile SMS, IVRS, radio, apps**, etc.	
	 Climate smart agriculture	Establishment of an ecosystem of **youth entrepreneur extension agents** providing digital services to beneficiaries.	
	 Digital upskilling	Capacity building of **subject-matter specialists to produce videos** that are publicly available, for example on YouTube, and train public extension officers to screen those videos among their communities.	
	 Digital upskilling	**Promoting the use of digital tools** for producers through community outreach and training programs.	
Digital Financial services	 Digital financial services	Provision of **satellite imagery data linked to digital farmer profiles** to support climate insurance claims and provide evidence of losses and predictions to help mitigate effects from severe flooding/drought and pests.	• Bundling of services, and coupling this to mobile money will ensure a higher success rate, especially in the short term. • The regulatory environment must support emerging business models that link digital agriculture with digital financial services. • Considering the use of other currencies (including cryptocurrency) could reduce market volatility. • Further enabling agri-entrepreneurs and private sector financial service providers to bundle services by enhancing the ease of doing business and stimulating public-private partnerships.
	 Digital financial services	**Pilot and select digital financial services** to understand what works best in the given context, including coupling tools with the use of digital credit scoring profiles.	
	 Digital upskilling	Promoting the use (and how to **safely select and use services**) among the farmer and pastoralist communities through community outreach and training programs.	

Legend

Recommendations align to ClimSmartDigitalAg pillar from the AAAP as follows:

Types of Adaptation Practices: Climate services | Climate smart inputs | Climate smart agriculture | Climate proof market access | Digital upskilling | Digital financial services

Level of value chain: Input | Production | Market | Along the value chain

10. Summary and Outlook

Projections for 2050 show that 73 % of Kenya's agricultural land is under threat from a combination of high-to-extreme climate variability, heat stress, and droughts; another 18 %, instead, is vulnerable to the effects of a combination of high-to-extreme climate variability and droughts. Agriculture in Kenya is mainly rain-fed and thus highly vulnerable to climate variability, increasing temperatures, and droughts. More than USD 1.86 billion in crop and livestock value and 15 million rural Kenyans are exposed to climate hazards every year. This situation has substantial implications for the rural populations whose livelihoods depend on agriculture. Impacts include livestock losses, crop failures, and lower incomes. Maize production, a critically important crop for Kenya, is vulnerable under climate change scenarios, and losses are estimated at USD 100–200 million annually by 2050 (Herrero et al., 2010). Moreover, the staple crops' yield growth rate is expected to decrease by 12% to 23%, while food prices will increase by 75% to 90% by 2055 (FICCF, 2013). Climate change also causes geographical shifts and reductions in the area suitable for production. On the other hand, this might lead to crop diversification and intensification opportunities in some places. Understanding and addressing climate change issues is an integral component of effective agricultural planning and policy development. Carefully planned investments towards improving the country's adaptive capacity will counter these effects to an extent. Using digital tools along the value chain will ensure rapid adoption, higher quality, and a larger scale of impact for adaptation solutions.

Digital and data-technologies can help Kenya become more resilient to climate shocks. Enabling the use of digital tools for adaptation practices will increase the speed and scale of the implementation of adaptation practices. This would include better water management for drainage and irrigation, the use of improved crop varieties and livestock breeds, crop diversification, changes in cropping patterns and planting calendars, and livelihood diversification for smallholders. Digital technologies are central to informing decisions about adaptation practices, as they enhance their precision, timeliness, efficiency, and impact. Technologies such as blockchain, artificial intelligence, the Internet of Things, machine learning, sensors, and drones can revolutionize how data is collected, stored, and analyzed along agricultural value chains. Integrating these digital solutions into agriculture can improve efficiency by increasing product quantity and quality, decreasing financial and labor costs, providing information to support management decisions, reducing losses, protecting assets against unexpected shocks, and ensuring the effective and sustainable use of resources. However, in Kenya's near future, digital technologies such as short message service (SMS), interactive voice response (IVR), the internet, and apps on mobile phones have the greatest potential for disseminating information on adaptation practices at scale.

Kenya is far ahead of other African countries regarding basic infrastructure for collecting, storing, and using weather and climate data and the development of early warning tools. Weather stations and weather forecasting as public services provided by the Kenya Meteorological Department (KMD) are already present. However, further investment and policies to strengthen their function will enhance the effective implementation of climate information and advisory services. The country also operates the Kenyan Space Agency, which focuses on agriculture, disaster management, and resource management, among other things. Additionally, a Drought Early Warning System and a Predictive Livestock Early Warning System have been developed. Kenya is also considered a leader in the digital agriculture sector. The country enjoys one of Africa's highest levels of mobile phone network coverage and the largest number of active digital agriculture services. However, these solutions have not yet achieved mainstream use, and many farmers remain unaware of their existence and benefits.

When addressing critical barriers to the use and uptake of digital technologies, digital tools for adaptation can jumpstart adaptation efforts. However, several factors hinder the adoption of digital

tools, including high costs, low digital literacy, limited infrastructure access, and weak enabling policy environments. Additionally, despite elevated levels of network coverage and mobile phone penetration, there remains a gender gap in mobile internet usage, partially because women are less likely to purchase their own smartphones due to problems with affordability and are less aware of the internet. This makes women less likely to use digital agricultural apps, exacerbating the gender gap in agricultural productivity. Designing services specifically for women by applying an inclusive lens represents a promising opportunity to overcome this drawback. These challenges could be tackled by pairing the services with public awareness campaigns and demonstrations involving public extension systems. Even though Kenya is known for its entrepreneurial and advanced digital ecosystem, the number of digital workers prepared to develop and manage digital solutions remains low, and talent is concentrated in the largest cities. There is a significant opportunity to grow the digital workforce, particularly in rural areas and in the agricultural sector. The urgent need for regulation and data protection and cyber security practices also needs to be addressed in the short term. There is also ample opportunity for public-private partnerships to build additional infrastructure and analytical capacity to support climate services. In combination with other site-specific, decision support tools, timely and accurate weather services stand to substantially improve national agricultural productivity and GDP while lessening damage due to extreme weather.

The government, national and international research institutions, non-profit organizations, and the private sector all play an essential role in the digital soltutions for adaptation of the agricultural ecosystem. The government is an important player mainly because it has established an enabling environment and policies in the digital ecosystem. However, Kenya's main driver behind the innovation and development of digital (adaptation) tools lies in the private sector, which is evident by the number of SMEs currently operating in the country. Several national and international research and non-profit organizations back this development. This happens through research and setting up pilots, implementing and scaling initiatives, or by developing financial support capacity, often through partnerships with the public sector. To ensure the use of good digital technologies for adaptation and reduce redundancy, it is important to navigate Kenya's current digital ecosystem. However, given the significant scale of impact that climate change will have on Kenya, further investments in basic infrastructure, enhanced institutional and end-user capacity, a flourishing digital ecosystem, and target adaptation interventions are necessary for successful climate change adaptation.

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12. Annex – Stakeholder list

Stakeholders bring different perspectives, values and expectations that can help to build a better understanding of the nature and scope of the climate risks and opportunities, and how best to approach them. The table below indicates some of the different actors involved in climate change and management in Kenya. They include donors, governmental organizations, NGOs, digital adaptation platforms, private sector, media and farmers among others.

CATEGORY	COMPANY/PLATFORM/ INITIATIVE	DESCRIPTION OF DIGITAL AND/OR ADAPTATION SOLUTIONS OFFERED
(INTERNATIONAL) NON PROFIT ORGANIZATIONS -INCLUDING RESEARCH, UNITED NATIONS, DONOR AND (I)NGOS ORGANIZATIONS	World Bank	Working with the Ministry of Agriculture, Livestock and Fisheries. They have allocated a lot of funds for issues related to adaptation.
	African Development Bank	Through the Africa Climate Change Fund, AFDB has allocated funds towards climate change adapatation and mitigation.
	CGIAR	CGIAR is a global research partnership consisting of 15 reseach centers working for a food secure future dedicated to reducing poverty, enhancing food and nutrition security, and improving natural resources. They have several programs and projects around reseach and implementation of digital technologies for agriculture and climate adaptation in Kenya. This is mostly done in partnership with local oragnisations and the government.
	BioProtection Portal (from CABI)	The CABI BioProtection Portal is a free, web-based tool that enables users to discover information about registered biocontrol and biopesticide products around the world. It helps growers and agricultural advisors to identify, source and correctly apply biocontrol and biopesticide products against problematic pests in their crops.
	Food and Agriculture Organization of the United Nations (FAO)	They introduced the concept of Climate Smart Agriculture. Their role is to assist communities to adopt new technologies, providing seeds, agricultural inputs, and food. Fao also gives advice to MoALF on policy, technical advice, and it has a Mitigation of Climate Change in Agriculture Programme (MICCA) that monitors and assesses greenhouse gas (GHG) emissions and the mitigation potential in agriculture.
	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)	It funds many activities and it is involved in sustainable land management. They provide technologies and inputs for farmers, and are running the Green Innovation Centers.
	Kenya Markets Trust (KMT) agri-inputs and services partnerships	Supports commercialisation of climate-smart products and inputs targeting smallholder farmers through closing gaps in value chains and overcoming barriers in business enabling environments.
	Mercy Corps - Mercy Corps AgriFin	AgriFin works with companies like AgriTech companies and financial institutions to design, test, and scale products and services that can transform agriculture for small farmers. Through AgriFin, farmers receive the services which include, access inputs like seeds, access to markets, and financing.
	Plantwise Plus (from CABI)	CABI introduced Plantwisewise plus by establishing networks of local plant clinics run by trained plant doctors, where farmers receive practical plant health advice. Plantwise has strengthened plant health systems by working in partnership with the public and private sectors. The programme has contributed to the awareness-raising and detection of new pests and informed policy, research and planning through field-based evidence. Through Plantwise, the recommendation of "red list" pesticides - chemicals that are banned or restricted by international agreements - by agricultural advisory officers has halved.
	PRISE (from CABI)	It is a Pest Risk Information Service Project of CABI. PRISE Utilizes earth observation data and plant and pest life-cycle models to create pest alerts. It leverages the existing network of Plant Health Specialists from Plantwise and extension agents. Currently CABI is trying to develop a sustainable business model by selling the service to large-scale producers and the agriculture insurance sector.
	UNDP, Sustainable Land Management - Agro-Pastoral Kenya	Creates and increases awareness on climate change impacts on the livestock sector.
ORGANIZATIONS PROMOTING DIGITAL	iHub	iHub accelerates regional technology. It serves technology to the community, by connecting organizations and people, building market-relevant solutions.
	Nailab	Nailab provides a platform where startup entrepreneurs can leverage on technology, knowledge, and funding opportunities to solve problems faced by emerging markets.

CATEGORY	COMPANY/PLATFORM/ INITIATIVE	DESCRIPTION OF DIGITAL AND/OR ADAPTATION SOLUTIONS OFFERED
PRIVATE SECTOR	Apollo Agriculture	It bundles everything a farmer needs: financing, farm inputs, advice, insurance, and market access, when possible. Satellite data and machine learning enable better credit decisions, and automated operations keep costs low and processes scalable. Apollo builds credit profiles for unbanked smallholders using machine learning models that process large volumes of customer data, including satellite data of customer fields. Apollo customers receive guidance on farming techniques through an IVR service, accessible through any phone as a pre-recorded phone call.
	Arifu	Arifu uses Interactive SMS and chatbots to tailor content to the needs of individual users, providing basic crop and livestock management content linked to a crop calendar and customized for the learner and basic pest/diseases information based on a crop. They operate in Kenya, Tanzania, Nigeria, Zambia and Rwanda. The major value chains they offer information about are: potatoes, maize, cabbages, tomato, rice, dairy and chicken.
	FarmDrive	It uses mobile phones, alternative data, and machine learning to close the critical data gap that prevents financial institutions from lending to creditworthy smallholder farmers. FarmDrive connects, through mobile phone, smallholder loans and financial management tools. It collects data, including individual, socio-economic, demographic and satellite information. This information is then analyzed by machine learning algorithms to produce relevant credit scores for smallholder farmers, and decisioning tools that enable financial institutions to develop small-scale agriculture loan products.
	Hello Tractor	They connect tractor owners and smallholder farmers through a farm equipment sharing app, using the Internet of Things, and have supplied 250,000 farmers since 2017 in Kenya.
	iProcure	An agricultural supply chain platform. In addition to complete procurement and last mile distribution services, they provide business intelligence and data-driven stock management across the supply chains. They have storage facilities strategically located to ensure extensive reach to the rural consumer. Their business intelligence consists in knowing where customers are, and analyzing the market share and real-time sales data and product performance. iProcure partnered with Digifarm for input provision.
	Kuza	Kuza provides portable digital kits, designed to work off grid and without internet, to offer personalized advisory & information services to their farmers using HD video content in local languages.
	Pula	It designs products bundling insurance and agricultural inputs (seeds, fertilizer, credit) for small-scale producers. It leverages on remote sensing, GIS, and ground yield assessments. It offers digital extension to farmers.
	Ulima app & Enlima (by Technobrain)	Ulima app has been rolled out in Kiambu, Nakuru and Lakipia counties. It provides weather forecasts, and it is planned to provide precision recommendations. The current business model is to charge for 25% of the service and provide 75% for free.
		Enlima is an online platform linking farmers to markets, with a large data processing and analytical capacity.
	Ujuzi Kilimo	Provides farm specific recommendations (fertilizer, agro-weather advisory) based on data collected with the Ujuzi hand-held soil-testing device, weather forecasts and in-house data analytics. The device captures soil characteristics, topography and environmental data which is analyzed by experts to provide actionable recommendations.
	WeFarm	A scalable technology startup doing cutting edge work on machine learning. They provide a platform where farmers connect with one another to solve problems, share ideas, and spread innovation, for free, and without needing an internet connection, since WeFarm works even through SMS. Utilizing the latest machine learning technology, Wefarm's service gets bespoke, crowd-sourced information to help farmers increase yields, gain insight into pricing, tackle the effects of climate change, source the best quality seeds, fertilizer, loans and diversify their agricultural interests. They have a Natural Language Processing (NLP) that identifies three regional African languages – Kiswahili, Luganda, and Runyankore – in addition to English.
	Acre Africa	Service provider present in Kenya, Tanzania and Rwanda. It works with local insurers, linking farmers to them, and facilitating investment in their farms. The offered products vary from crop, livestock and index insurance products to shield farmers against unpredictable weather conditions. The ACRE Africa team undertakes risk assessment, product development and risk monitoring to facilitate access to crop and livestock insurance products for smallholders.

CATEGORY	COMPANY/PLATFORM/ INITIATIVE	DESCRIPTION OF DIGITAL AND/OR ADAPTATION SOLUTIONS OFFERED
PRIVATE SEC	Agrics/Geodatics	Uses farmer data, earth observation data and crop growth model to determine exact N-P-K needed to obtain realistic yields and translates into fertilizer recommendations. They work with fertilizer companies to develop the exact

		blends needed in the farms. The company also manages logistics of getting fertilizer to farmers. Reaching more than 20,000 farmers in Kenya.
	AgriWallet	Farmers, when they sell their agricultural produce, receive the payment into their M-PESA account, and they can automatically save for inputs, and gain access to loans. When a transaction is done, AgriWallet pays farmers directly and buyers pay AgriWallet later, improving farmers working capital, by stimulating supply and reducing administration costs.
	aWhere	Predictive climate modeling for agriculture based on 1.7 million virtual weather stations globally. It uses a blend of observed and satellite data to generate a 15-day forecast at 9km x 9km scale. It provides 1) In-time weather data and 2) Advisories that combine crop models with weather data. Data is digitally accessible.
	Conservation Agriculture for Food Security (CA4FS)	It aims to build the resilience of smallholder farmers and other actors involved in the agricultural value chain in Machakos and Laikipia counties, through enhancing the adoption of conservation agriculture practices and building value chain linkages to improve access to climate-smart technologies, reliable suppliers and markets.
	CropIn	It provides a whole farm management solution linked to geotagged farm locations including weather info, crop management advice and pest and diseases information.
	Media	Provides vital information at times of emergency. Their services include warning of imminent floods and explanations about how best to deal with drought.
	Mediae	Multiple digital solutions. For example the TV program Shamba Shape Up, which reaches over 5 million viewers per week. Linked to it there is the iShamba platform, which sends through SMS to send information based on location, both for crops and livestock, covering full value chains. They also distribute county-level forecasts from the Kenya Meteorological Department. Another service they provide is Identification of pests and diseases using mobile messaging and images through WhatsApp.
	MobiGro (by the Kenya Commercial Bank)	It is a mobile-based digital credit facility allowing farmers to access agribusiness loans, savings, insurance, market information and training. Farmers can sign-up throughM-PESA.
	MyAnga	MyAnga is an application designed to provide weather forecast information about Marsabit and Isiolo Counties in northeastern Kenya. The application was developed as one of the results of the CLI-MARK initiative (Enhancing Market Response to Resilience in Livestock Value Chain in Eastern Africa), and it consists of a web dashboard and weekly SMS subscription to convey information about the weather.
	Northern Rangeland Trust (NRT) LivestockWORKS	It aims to support strategic destocking among pastoralists to avoid large herds that cannot be sustained at times of drought. They also support access to inputs, such as feed supplements, through value chain integration.
	MoAINFO from Precision Agriculture for Development (PAD)	PAD is a Core partner of the Ministry of Agriculture through the MoAINFO platform. The platform, which started providing information about Fall Armyworm, is now expanding to include more comprehensive advisory services for 6 main crops. The advisory provides, based on farm characteristics, management recommendations and it provides weekly weather forecasts. The service is currently being piloted in 2 counties. The main value chains are maize, beans, irish potatoes, sweet potatoes, pigeon peas, bananas.
	One Million Farmers Platform	Through a competitive call, the leaders of this initiative, identified the most promising agri-tech innovations to bring to farmers, onto one impactful digital platform. The platform includes technologies such as mobile apps, data analytics, and digital extension. It also involves solutions that enable suppliers to aggregate farmers' demand for inputs like seeds and services like tractors, which can then cost-effectively be delivered to farmers at the farm gate. Other promising approaches include financial services, enterprise development, market access, and data analytics. The platform offers to the participant solutions, mentorship, training and exposure to reach the necessary scale.
	Safaricom's Digifarm	Safaricom’s integrated mobile platform of digital services for farmers. It brings together multiple input and service providers into one platform. The service is accessible on a basic feature phone. Farmers can order inputs, engage in learning, access credit, harvest cash loans, insurance, connect with buyers, obtain soil testing and aggregate their products. The platform also Introduced DigiSoko, an open marketplace for agricultural produce.
	SoilCares	Hand-held testing device that provides in-field monitoring of soil nutrients via a smart-phone app and hand-held printer. The App delivers assessment and management advice including target yield, soil status, actual nutrient need, soil correction plan and suitable crop types.

CATEGORY	COMPANY/PLATFORM/ INITIATIVE	DESCRIPTION OF DIGITAL AND/OR ADAPTATION SOLUTIONS OFFERED

PRIVATE SECTOR	Sunculture	SunCulture is a company focused on solar-powered water pumps and drip kits, making it cheaper and more water-efficient for farmers to grow. Half of early adopters of the product have reported an increase in farm yields and income.
	VirtualCity	Virtualcity is a technology firm that develops and delivers mobile solutions across the Agri and Supply value chain. They provide digital tools that accelerate financial inclusion for farmers and de-risk investment decisions for financial service providers.
PUBLIC SECTOR	County Governments	Their role is to integrate and mainstream climate change actions, interventions and duties into County Integrated Development Plans (CIDPs).
	Kenya Agricultural and Livestock Research Organization (KALRO)	Main research institution in the country, and vital for research related with new varieties of seeds and animal breeds. They also play an important role in providing weather and agronomic information, and run the Kenya Agricultural Observatory Platform (KAOP) where farmers can access localized data on daily weather updates. KALRO also plays a crucial role in the development of digital tools for adaptation, partnering and facilitating the process.
	Kenya Agricultural Observatory Platform (KAOP)	A KALRO run digital platform that provides real-time and historical records of all relevant weather variables including short-term weather forecasts. The platform provides agronomic content that allows farmers to monitor and predict the current situation, acting accordingly. Farmers can visit the KAOP website or sign up for SMS alerts.
	Kenya Cereal Enhancement Programme (KCEP)	Support small-scale cereal and pulses producers to access climate smart technologies and services. They have also implemented an e-voucher program, which allows producers in critical situations to access the inputs they need.
	Kenya Climate Smart Agriculture Programme (KCSAP)	A Government of Kenya project supported by the World Bank, implemented over a five year period (2017-2022). It works with farmers and pastoral communities, aiming at increasing agricultural productivity and enhancing resilience to climate change risk. Additionally, in the event of an eligible crisis or emergency, the project provides immediate and effective response.
	Kenya Livestock Insurance Program (KLIP)	It aims to develop a livestock insurance scheme to provide affordable safeguards to support vulnerable pastoralists to keep more livestock alive during times of drought.
	Kenya Meteorological Department (KMD)	The KMD makes publicly available a wide range of products and services, including weather forecasts. It operates 40 synoptic stations, in which data collection is done manually. Additionally, there are around 600 gauge rain stations operated by private observers. In recent years the KMD has installed a number of Automatic Weather Stations (AWS), but the data is not yet fully integrated into meteorological applications mainly because the quality of the AWS datasets is not yet well known.
	Mbegu Choice	Mbegu Choice helps farmers, agro dealers and extension by providing well suited seed varieties for their areas. The platform asks users to provide information, including county, agro ecological zone and type of crop. Upon filling in these details, the system automatically provides a list of seed varieties best suited for their location.
	National Climate Change Secretariat (NCCS) in the Ministry of Environment and Natural Resources.	The NCCS is the National Focal Point for the UNFCCC. It oversees coordination of all climate change activities, working with climate change coordination units in different ministries, departments and agencies to ensure that climate change is mainstream in the different sectors of the economy.
	National Drought Management Authority (NDMA)	A key institution in enhancing adaptive capacity. Established in 2011, NDMA is mandated to establish mechanisms to ensure that drought does not become famine and that impacts of climate change are addressed. It oversees adaptation and resilience building in the arid and semi-arid areas. It is also the secretariat of the Common Programme Framework in Ending Drought Emergencies in Kenya.
	National Government Sectoral Agencies	Reports annually to the National Climate Change Council on the status and progress of all assigned climate change duties and functions.
	The National Environmental Management Authority (NEMA)	A semi autonomous agency in the Ministry of Environment, it is a national Implementing Entity (NIE) for the Adaptation Fund and the Green Climate Fund (GCF)