Digital Climate Adaptation in Agriculture Profile for Zimbabwe

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June 2023

Acknowledgement

The authors are indebted to The Center for Agriculture and Food Policy (CAFP), which is a registered Trust for agricultural policy research, outreach and capacity building. CAFP was IWMI's local partner in Zimbabwe for the project that led to this work. The authors are also indebted to the International Water Management Institute, the Global Center on Adaptation, and the African Development Bank for technical leadership on the key stages of the research. Further gratitude goes to all the various stakeholders and personnel for their comments, inputs and roles they played in the process of carrying out this research in Zimbabwe.

This work was a collaborative effort between the International Water Management Institute, The Global Center on Adaptation, the African Development Bank, and The Center for Agriculture and Food Policy (CAFP).

Correct Citation : Mayoyo A, Chapoto A, Matchaya G, Aheeyar M, Chiwunze G, Ebrahim G, Ajayi O.C, Afun-Ogidan O, Fakudze B, Kasoma-Pele W. 2023. *Digital Climate Adaptation in Agriculture Profile for Zimbabwe.* Internatinal Water Management Institute, Global Centre on Adaptation, and the African Development Bank. Colombo, Rotterdam and Abidjan

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Acronyms

AAAP	Africa Adaptation Acceleration Program
AfDB	African Development Bank
CDMA	Code Division Multiple Access
COMESA	Common Market for Eastern and Southern Africa
COVID	Coronavirus disease
CPU	Civil Protection Unit
CNFA	Cultivating New Frontiers in Agriculture
EWS	Early Warning Systems
FAO	Food and Agriculture Organization of the United Nations
FCDO	Foreign Commonwealth Development Office
FEWSNET	Famine Early Warning Systems Network
GCA	Global Center Adaptation
GDP	Gross Domestic Product
GIS	Geographic information system
GMB	Grain Marketing Board
GPS	Global Positioning System
GoZ	Government of Zimbabwe
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	Information Communication Technology
IPCC	Intergovernmental Panel on Climate Change
ITU	International Telecommunication Union
IWMI	International Water Management Institute
LDC	Least Developed Countries
MLAWFRD	Ministry of Lands, Agriculture, Water, Fisheries and Rural Development
MOFED	Ministry of Finance and Economic Development
MSD	Meteorological Services Department
MW	Mega Watts
NGOs	Non-Governmental Organisation
POTRAZ	Postal and Telecommunication Regulatory Authority of Zimbabwe
RCP	Representative Concentration Pathway (RCP)
SADC	Southern Africa Development Community
SARDC	Southern Africa Research and Documentation Centre
SDGs	Sustainable Development Goals
SMS	Short Message Service
SIDA	Swedish Development Agency
TV	Television
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USD	United States Dollar
WB	World Bank
WHH	Welthungerhilfe
ZAMCOM	Zambezi Watercourse Commission
ZIMSTAT	Zimbabwe Statistical Agency
ZIMVAC	Zimbabwe Vulnerability Assessment Committee
ZRB	Zambezi River Basin
ZWL	Zimbabwe Dollar

1. Introduction

1.1. The Economy of Zimbabwe

Zimbabwe is a landlocked African country with an estimated population of 14.65 million people as of 2019 with females accounting for 52 percent of the population resulting in a sex ratio of almost 92 percent. ZimStat, 2017). The population of Zimbabwe is relatively young with 40 percent of the population estimated to be below the age of 15 and about 6 percent aged 65 years and above. Seventy percent of the population is based in rural areas with the rest residing in urban areas. The average household size is estimated at 4.2 persons per household (ZimStat, 2017). There is a high number of female-headed households, which highlights the need for gender-inclusive strategies to ensure these households have equal access to climate change adaptation technologies.

Zimbabwe has experienced major structural changes including hyperinflation, changes in the land tenure system, disruption of the agriculture sector and increased dependence on natural resources to spur economic growth. The period 2000 to 2008 saw the country experiencing a sustained decline in economic activities with real Gross Domestic Product (GDP) growth declining by close to 20 percent in 2008 and inflation rate increasing substantially pushing the country into hyperinflation in 2007 before it peaked at the end of 2008 (AfDB, 2010). Following the introduction of the multicurrency system, the real GDP growth rate rose by more than 10 percent per annum reaching a peak of 19.7 percent in 2010 before declining to minus 8.30 percent in 2019 (MOFED, 2020). The currency reforms resulted in an increase in inflation, which further nhanceshed the population, with the percentage of people in extreme poverty increasing from 29.5 percent in 2018 to 42.5 percent in 2019 (MOFED, 2020). In 2020, the real GDP growth rate was projected to decline to minus 4.1 percent owing to the impacts of the COVID-19 pandemic, which stalled economic activities (MOFED, 2021).

The economy is heavily dependent on mining and agriculture. However, political instability and continued unstable economic environment have severely damaged the country's economic potential. Agriculture is the backbone of Zimbabwe's economy, contributing 12-15 percent to Zimbabwe's GDP. Over 70 percent of the population livinglives in rural areas and are dependent on climate-sensitive livelihoods such as rainfed arable farming and livestock rearing, among others. Agricultural activities provide employment and income for 60-70 percent of the population, supply 60 percent of the raw materials required by the industrial sector and contribute 40 percent of total export earnings (FAO, 2021).

Rainfall patterns have become more erratic, unevenly distributed, uncertain, and unpredictable, resulting in crop failures that occur three out of every five years (World Bank, 2017). Weather uncertainty is contributing to enormous strain on smallholder production systems. Leading to high poverty rates (63 percent), and adversely impacting food security, health, water security, and freshwater ecosystems (World Bank, 2020).

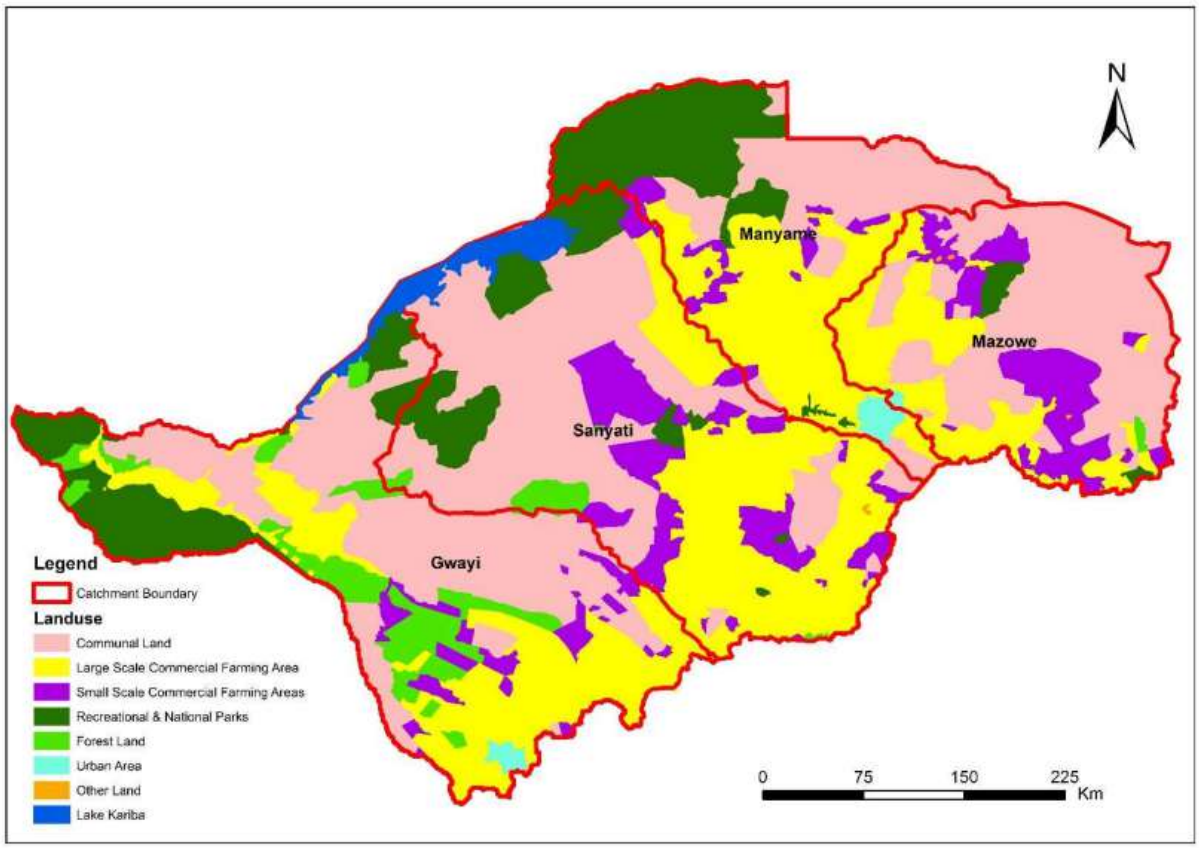
Zimbabwe has experienced negative impacts associated with climate variability and change, especially in the past decades, such as a significant increase in frequency and extreme events of drought and flash floods. The rainfall distribution has changed with a trend of late onset and early cessation of the rainy season. In Zimbabwe, 11 and 12 of its 52 districts are at risk of severe and moderate droughts respectively (Mudombi, 2013). Based on EM-Dat database[1], from 1900 to 2017, Zimbabwe has experienced 7 droughts, 22 epidemic occurrences, 12 floods, and 5 storms. These occurances have caused human life loss, 7,000 people have been reported to have died, more than 20 million people affected, causing estimated total damage of 950 million United States Dollars (USD).

[1] EM-DAT: The Emergency Events Database - Universite catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium. https://www.emdat.be/database

1.2. The Zambezi River Basin

The Zambezi River is the fourth-longest river in Africa, shared by eight countries namely, Zambia (42 percent of the basin area), Angola (18 percent), Zimbabwe (16 percent), Mozambique (12 percent), Malawi (7.5 percent), Tanzania (2 percent), Botswana (1.5 percent), and Namibia (1 percent) (Kling et al., 2014). The river is 2,574 km long with a basin area of 1.37 million km^2 and has an average discharge of 4,134 m^3/s at the outlet in Mozambique (World Bank, 2010). This report focused on the part of the Zambezi basin that traverses Zimbabwe – better known as the Zambezi Valley and stretches from Victoria Falls in Matebeleland North to Muzarabani in Mashonaland Central Province. The geographical map of the Zambezi basin in Zimbabwe is shown in the figure below.

Figure 1: Map of the Zambezi Basin in Zimbabwe



Source: http://gip.sadcgmi.org

Land cover in the Zambezi River Basin consists of rain-fed, forest, bushland, grassland, open water and irrigated land. The Zambezi River Basin is characterized by one distinct wet and one dry season. It exhibits high temporal and spatial variability in water availability and demands such that during the dry season demand frequently exceeds water availability, resulting in water-stressed areas (Hulsman et al., 2020). There is a distinct wet season from September to April and a dry season from May to August. In the semi-arid basin, potential evaporation (2,000 mm/year) exceeds precipitation (1,000 mm/year), especially during dry seasons (Schleiss et al., 2016). The Zambezi River Basin is characterized by extreme climatic variability, the river and its tributaries are subject to a cycle of floods and droughts that have devastating effects on the people and economies of the region, especially the poorest members of the population.

The basin is one of the most diverse and valuable natural resources in Africa. The Zambezi River flows through numerous game reserves and national parks, providing sustenance to a diverse array of game,

birdlife, and fish species. Its waters are critical to sustainable economic growth and poverty reduction in the region. In addition to meeting the basic needs of some 30 million people in cities and sustaining a rich and diverse natural environment, the river plays a central role in the economies of the eight riparian countries: Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia, and Zimbabwe (SADC/Zambezi River Authority, 2007).

The Zambezi River plays a significant role in the socio-economic lives of communities along the river, contributing approximately 24 percent of the GDP of the region. It constitutes a major tourism resource by providing spectacular settings, recreation facilities, and a means of transport, irrigation, and hydropower generation. Two large hydropower dams are located in the main Zambezi River, namely the Cahora Bassa Dam (2,075 MW) in Mozambique and further upstream, the Kariba Dam (2,130 MW) at the border between Zambia and Zimbabwe. The Kariba Dam provides power to both Zimbabwe and Zambia.

The Zambezi River Basin is endowed with natural resources: however, the basin remains underdeveloped and is characterized by widespread poverty, hence communities along the river are vulnerable to climate change hazards. An estimated 70 percent of the population in the Zambezi River Basin is rural based, is dependent on rain-fed agriculture, and are extremely vulnerable to climate change (SADC/ Zambezi River Authority, 2007). The Zambezi River Basin has a total of 5.2 million ha of arable land, with only 3 percent of the land under irrigation (ZAMCOM, 2019).

Other challenges currently being faced in the basin include unplanned development contributing to 51 percent of land in the basin being moderately degraded and 14 percent being highly degraded, resulting in the increased negative impact on the population and increased erosion compounding to siltation of the Zambezi River (ZAMCOM, 2019). High levels of deforestation and runoff are contributing to the reduction of groundwater reserves worsening the water crisis.

Objectives of the profile.

Whilst climate change hazards are going to impact both smallholder and commercial farming, smallholder farmers are more vulnerable because of their high dependence on natural resources and limited resources to cope. Smallholder farming forms the majority of farming systems including a high level of women participation which increases their vulnerability.

Globally, there has been increased cooperation and collaboration around key adaptation opportunities. The Africa Adaptation Acceleration Program (AAAP) was developed by the Global Center on Adaptation (GCA) and the African Development Bank (AfDB). The Africa Adaptation Acceleration Program seeks to collectively address Africa's adaptation priorities through transformative and innovative actions. Through scaling up the uptake of climate-smart digital technologies, and associated data-driven agricultural and financial services, at least 30 million farmers are expected to be reached in Africa by 2025. This will contribute towards increased food security and resilience for at least 10 million people in 26 Least Developed Countries (LDCs) in Africa. This process will be executed under four pillars:

- Pillar 1: Climate-smart digital technologies for agriculture and food security
- Pillar 2: Africa infrastructure resilience accelerator
- Pillar 3: Empowering youth for entrepreneurship and job creation in climate adaptation and resilience
- Pillar 4: Innovative finance initiatives

In line with the first pillar, which is climate-smart digital technologies for agriculture and food security, the GCA and the Bank are embarking on a project concerning climate-smart digital technologies around the Zambezi River Basin with a deep dive on the Zimbabwe and Zambia side. This profile seeks to improve climate change adaptation through scaling up of digital tools usage in Zimbabwe, specifically targeting

smallholder farmers such that they can be more resilient and food secure. One key output during the feasibility stage is the development of a country digital adaptation profile of Zimbabwe.

The objectives of the profile are as follows:

i. Conduct a stocktaking and needs assessment to identify digital innovation infrastructure, institutional capacity, policies and programs, ongoing activities, key partners, gaps and opportunities, including the identification of low-hanging fruit for necessary analytical work and adaptation investment prioritization.
ii. Summarize key information related to the state of digitization and the extent to which digital innovations are mainstreamed into ecosystem based adaptation, especially in the context of agriculture.
iii. Understand the enabling environment that governs adaptation as well as the extent to which adaptation uses digital innovation.
iv. Understand digital innovations challenges, the extent of penetration, their general cost structures, and the prevalent adaptation techniques among smallholder farmers.
v. Summarize the key institutional, policy and human capital challenges to digitization.
vi. Make recommendations on key actions and opportunities to be undertaken/pursued to mainstream adaptation to climate change.

The country profile will be useful in arriving at country-specific recommendations for upscaling the uptake of digital innovations in climate adaptation, in support of small and medium enterprises, smallholder farmers and their enabling environment.

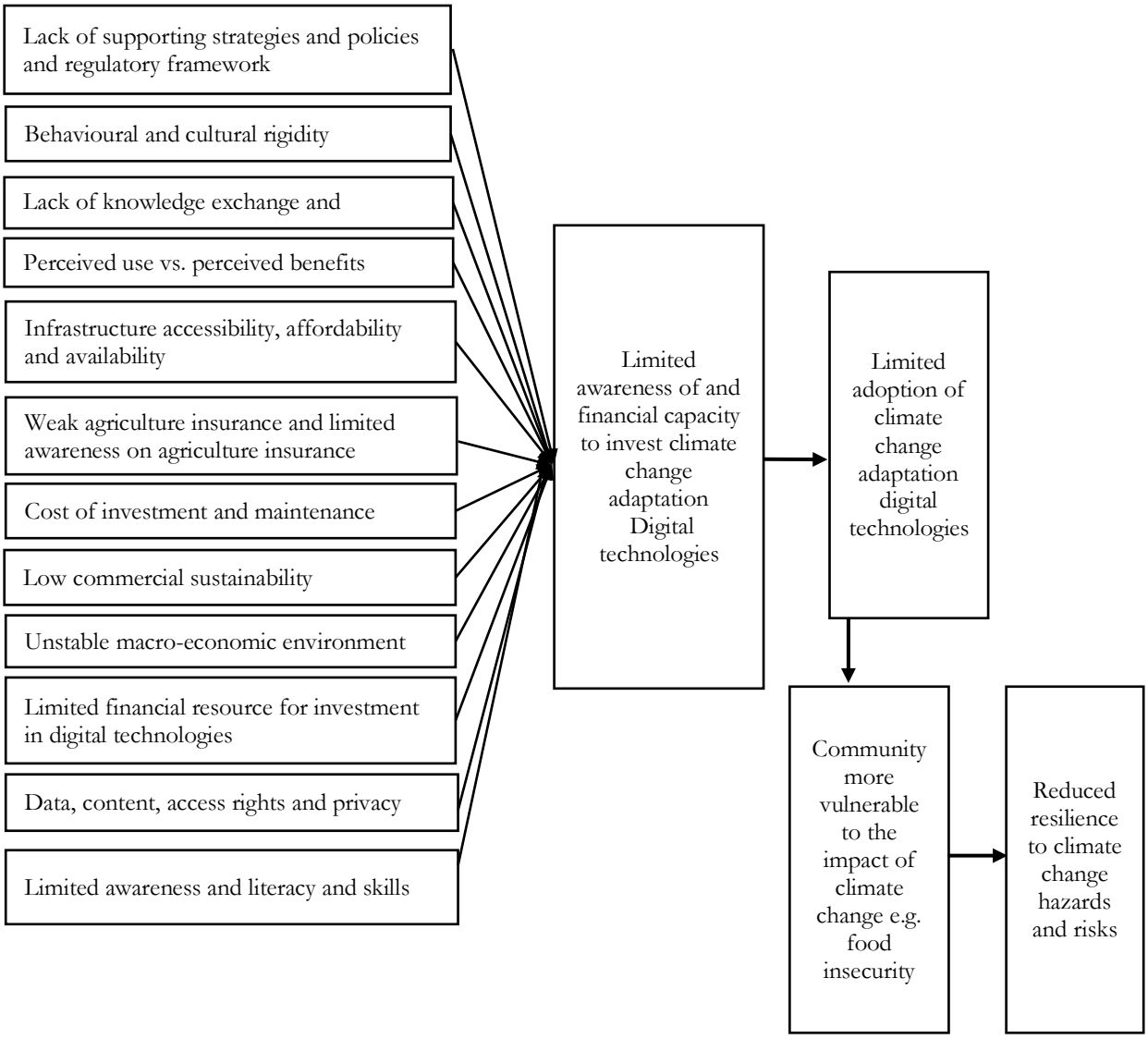
The report is structured as follows: it first presents the Conceptual Framework for digital technology adoption and upscaling followed by the study approach. It then highlights the most important climate hazards in Zimbabwe and the uptake and opportunites for scaling digital technology. The country context including the economic relevance of agriculture, water and energy follows. The profile then delves into: Zimbabwe's climatic risks; vulnerability and resilience; challenges and opportunities for digital adaptation; digital adaptation to climate change; digital adaptation readiness; and a summary of the profile. Key annexes present case studies on the use of digital platforms and the list of key regional stakeholders in digital technology adaptation. These regional stakeholders include: the Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL), the International Water Management Institute (IWMI), International Institute of Tropical Agriculture (IITA), the African Development Bank (AfDB), the Global Center on Adaptation (GCA), the Zambezi Watercourse Commission (ZAMCOM), the Southern Africa Development Community (SADC), the Common Market for Eastern and Southern Africa (COMESA) and the Food and Agriculture Organization of the United Nations (FAO).

1.4 Analytical framework for Digital Technology adoption and upscaling

1.4.2 Theoretical framework

This study is mainly concerned with the scaling of digital technology adoption as a solution for climate change adaptation and building of resilient communities. The theoretical framework explores the impact of barriers and constraints to the adoption and scaling of digital tools by communities. Figure 2 below highlights the critical path from adoption/use of technology and to investment targeting opportunities.

Figure 2: Theoretical framework for Digital Technology adaptation and upscaling

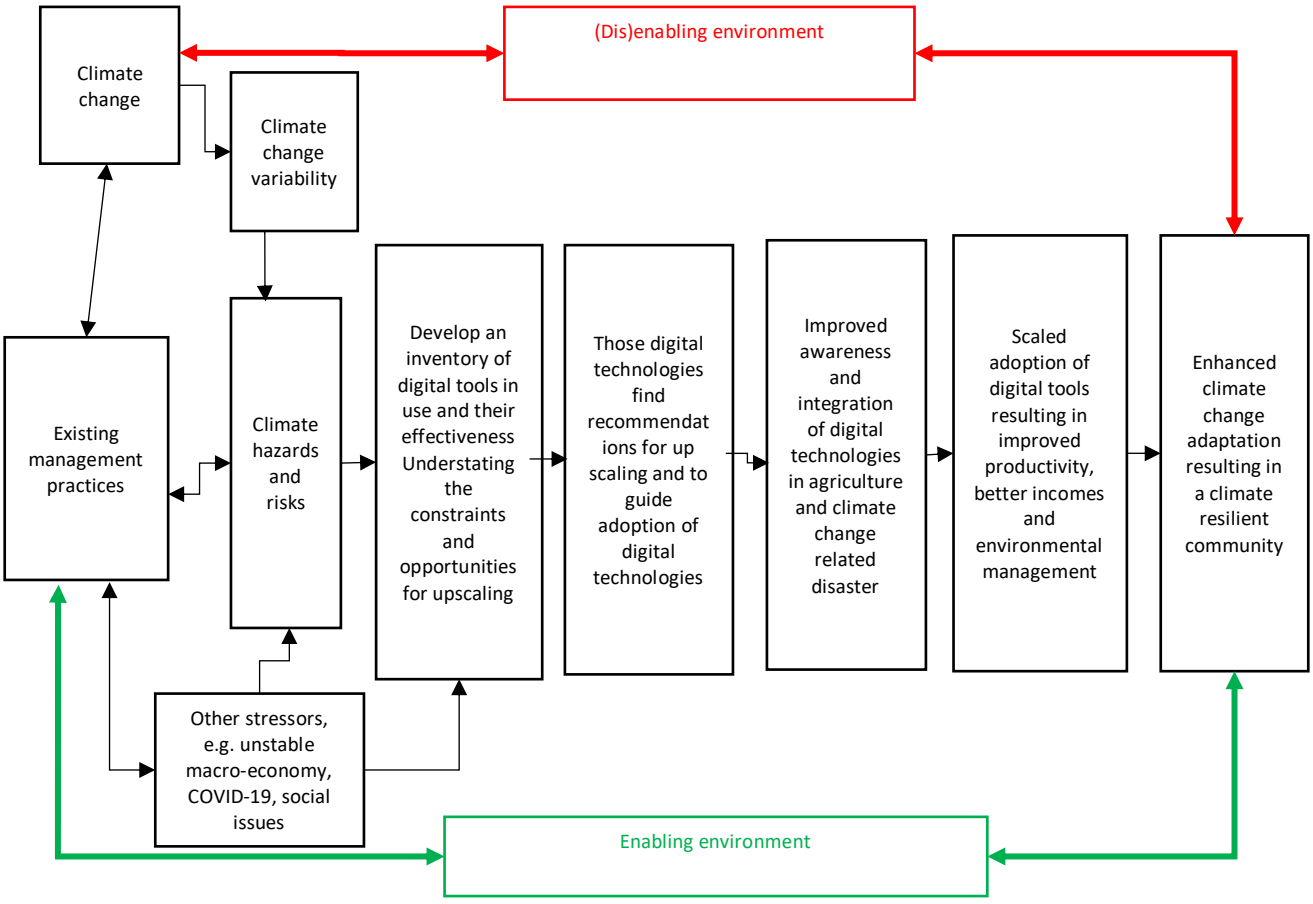


Source: Authors' Illustration

1.4.2 Conceptual framework

This conceptual framework takes on a theory of change approach that is expected during the transformation process as farmers adopt digital technologies. The conceptual framework captures the transformation process, starting by carrying out a situation analysis that helps us understand the smallholder context and how it influences their decisions and adaptive capacity. The situation analysis forms the background that will guide the identification of the digital solution that best suits farmers in their context. The findings are then used to package the information in a way that will capture farmers' interest such that their willingness to adopt digital tools to transform smallholder production systems. An enabling environment is required to facilitate adaptation and upscaling of digital technologies that nhance climate resilience communities whilst a dis-enabling environement discourages adoption and upscaling of digital technologies for climate change adapation in agriculture and exposes communities to climate hazards and risks. There are feedback loops to continuously monitor and evaluate the effectiveness of digital tools in addressing the climate-related challenges considering the digital world is dynamic (see Figure 3).

Figure 3: Conceptual framework for climate adaptation Digital Technology adoption and upscaling



Source: Authors' Illustration

1.5 Benefits of digital technology in agriculture

Digital agriculture plays an important role in agriculture value chain systems including influencing behaviour of farmers, input providers, processing and retail companies, and marketing companies. Adoption of digital tools in agriculture improves efficiency along production chain, improves access to information that can guide decision making and enable virtual transactions. Specific examples of digital technology applications in agriculture include digital and wireless technologies for data measurement, weather monitoring, animal monitoring, geospatial monitoring and precision application of water and chemicals. Satellite imagery in cropping is also another digital technology. This tracks and produces data on variable seed rates, seed depth and soil moisture. Digital infra-red light and heat sensors, when used with geographical system technology in drones, can be used to measure paddock crop health, and inform the decision on irrigation, pest management, fertilizer application and harvesting.

The major digital technologies used in agriculture include:

Technology used directly by farmers

i. Mobile devices and social media –for advisory services, information dissemination;
ii. Precision agriculture and remote sensing technologies (GIS, GPS and satellite imagery), crop forecasting, precision applications of fertilizers and chemicals;

Technology for farmer support systems

iii. Big Data, cloud, analytics and Cybersecurity-agricultural data analysis, advisory services;
iv. Integration and coordination (blockchain, ERP, financing and insurance systems)-weather indexed insurance;
v. Intelligent systems (Deep Learning, Machine Learning and Artificial Intelligence and robotics and autonomous systems). Technology such as AI, machine learning (ML) analytics, and connected sensors could foster increase in yields, improve the efficiency of water and other inputs, and build sustainability and resilience across crop cultivation and animal husbandry. It can also eliminate information asymmetry by increasing access to data to all stakeholders, reduce operational and transaction costs by reducing manual and paper processing, improve access to markets by connecting farmers directly to consumers, enable access to finance by using alternative data to evaluate the creditworthiness of farmers and increase the ability to perform sustainable farming techniques that ultimately help the environment (Trendov et al., 2019).
vi. Blockchain technologies to enable the traceability of information in the food supply chain and thus helps improve food safety.

Digital technologies can be applied to all aspects of agrifood systems and reflects a change in generalized management of resources towards highly optimized, individualized, intelligent and anticipatory management, in real time, hyper connected and driven by data (Trendov et al., 2019). There are still opportunities to increase and cascade the benefits of digital technologies in climate adaptation in agriculture.

1.6 Methodology for Digital Adaptation in Agriculture for the Zambezi basin

Figure 1 above shows the study area which is the part of the Zambezi Basin in Zimbabwe. The study made use of a mixed approach of qualitative and quantitative analysis of available data to profile digital climate change adaptation tools for Zimbabwe.

Data collection tools

Data collection tools utilised in undertaking this study include a desk review of both primary and secondary data, and consultation workshops. Three research questions guided the research process as summarised in Table 1. The first question seeks to understand the nature of climate hazards facing the Zambezi River basin, and climate vulnerability of the people in the Zambezi basin. The second question identifies digital tools being used and that can be scaled to improve adaptive capacity and resilience. The third question maps the transformation process through implementation of the digitalization process towards the achievement of increased productivity, improve food, income and nutrition security and a resilient community.

Table 1: Summary for analytical methods used for each objective

Research Question	Research Objective	Data collection method
What are the climate hazards and impacts experienced in the Zambezi basin part of Zimbabwe?	To understand climate change vulnerability based on the climate hazards experienced by households in the Zambezi basin communities.	Literature review, stakeholder consultations
What is the potential contribution of digital tools to climate change adaptation on the portion of the Zambezi basin area inside Zimbabwe?	To develop and understand digital tools that enhance high adaptive capacity to climate change and improve resilience the Zambezi basin communities.	Literature review, key stakeholder consultations
What are strategies that can be used to scale adaptations through digitalisation in the Zambezi basin?	To evaluate opportunities and barriers for scaling digitalization as a climate change adaptation solution in the Zambezi basin.	Literature review, key stakeholder consultations

Source: Authors' Illustration

The primary goal is to generate actionable recommendations for upscaling the use of digital technologies in agriculture that can be mainstreamed into the ZAMCOM's Plan for the Integrated Development and Adaptation to Climate Change (PIDACC).

2. Highlights

Zimbabwe is a signatory to a number of protocols and agreements under the United Nations Convention on Climate Change (UNFCCC). It has crafted several policies and strategies to actualize the aspirations of the protocols and agreements. These include, the Agriculture and Food Systems Transformation Strategy (2020-2025), National Agricultural Policy Framework (NAPF 2019-2030), National climate policy, National Climate Response Strategy, National Determined Contributions, National Adaptation Plan, National Climate Change Learning Strategy and all these are guided by National Development Strategy 1 (national blueprint) and the Sustainable Development Goals. These support development of agricultural value chains for the benefit of the country and the sector.

Whilst digital technology adaptation is very important, its success is influenced by the presence of enabling environment. Key factors that affect digital technology adaptation include the economic, political and social environment. The Zimbabwean economic environment is supportive of use of digital technologies in climate change adaptation in agriculture and the other economic sectors. There is a stand-alone ministry responsible for Information Communication Technologies responsible for creating an enabling environment for the adoption and use of information and computer technology (ICT)-based technologies.

Investments in digital technologies in the Zambezi River Basin is also supported by incentives to companies in those areas such as 5-year tax break, repatriation of 100 percent of dividends, among others.

The mobile penetration rate in Zimbabwe declined by 2.7 percent to reach 87.8 percent in 2021, from 90.5 percent recorded in 2020. Despite the drop, coverage is still very high according to POTRAZ (2021). Quarterly mobile voice traffic has been on the rise growing from 1.33 billion minutes in Q1 2020 to 2.11 in Q3 2021 (POTRAZ, 2021).

Digital technologies require special skills in ICT and there is a need to promote skills development in the areas starting at the primary school level. Key analytical skills are required to keep pace with trends in climate change developments. Some of the climate hazards and shocks occurring in the country includes drought and floods are also affecting the Zambezi communities and it is likely to get worse leaving many vulnerable. In addition, there is a need for improvement in climate adaptation policies, climate adaptation financing, raising awareness coupled with increased access to digital technologies.

A number of digital technologies needed for climate change adaptation ranges from improving production at the farm level, to marketing and receiving climate related information. There is an understanding that whilst these technologies are needed, they are associated with costs to do with acquiring these technologies. Furthermore, there is a need for innovative financial mechanisms, because access to finance is a key constraint for adaptation to climate change.

Due to limited resources in Zimbabwe, adoption of digital tools is low, especially in smallholder production systems - yet they form the majority of the farming population. To address the challenges at the production level there is need for awareness and capacity building of producers and other value chain players to increase adoption of digital agriculture technologies. This is expected to increase productivity within the farming system without the need for expansion of agricultural land. However, as a result of the unstable macroeconomic environment, the cost of investing in digital tools is contributing to low adoption for example whilst, smallholder farmers understand the need to adopt irrigation system, the cost of investing is too high, coupled with a lack of title deeds and these farmers cannot use the land as collateral security when accessing loans.

Zimbabwe still has many opportunities to expand its use of digital adaptation solutions. Improvement in network range to catch up with technological advancements around the world and within the region is also key.

3. Country Context

3.1. Economic Relevance of Agriculture

Agriculture is important in ensuring food and income security in the smallholder production system that makes up 90 percent of the rural population. Smallholder agriculture is the main source of livelihood for the majority of the population, the performance of agriculture is a key determinant of rural livelihood resilience and poverty levels in the country. General challenges facing smallholder farmers include low and erratic rainfall, low and declining soil fertility, low investment, shortages of farm labour and draft animals, poor physical and institutional infrastructure, poverty and recurring food insecurity. Agricultural production is also vulnerable to periodic droughts and sometimes floods for example in areas such as Muzarabani (FAO, 2021).

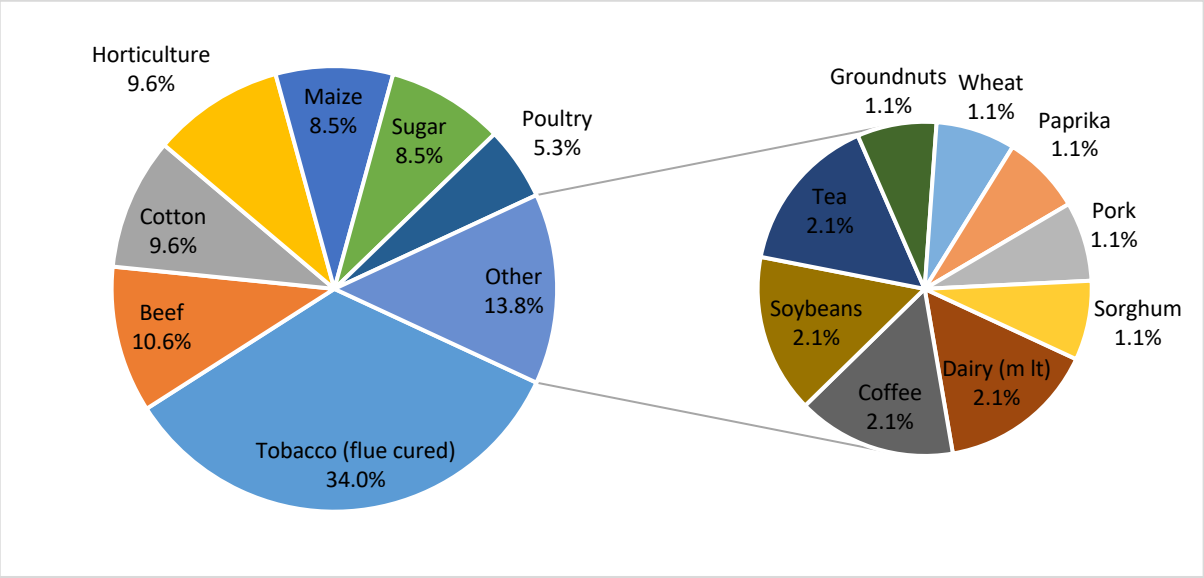
The total agricultural area is estimated at 16.2 million ha, of which 4.1 million ha is cultivated and 12.1 million ha is under permanent pastures. The country's forested area declined from over 22 million ha in 1990 to around 15 million ha in 2012 (FAOSTAT, 2015). The country produces a variety of crops which

include grain crops such as maize, sorghum, mhunga, rapoko, oilseeds (sunflower, groundnuts and soya beans) and other industrial crops such as tobacco, cotton, edible dry beans and paprika.

Agriculture contribution to the economy has been on a declined from 20.7 percent of GDP to 10.8 percent between 1985 and 2016 and subsequently 9.8 percent in 2020 ((MLAWFRD, 2020). Agriculture GDP has largely been dominated by production of cash crops namely, tobacco and cotton, which accounted for 34percent and 9.6percent of agriculture GDP whilst food crop production such as beef, horticulture, maize and sugar accounted for 10.6 percent, 9.6 percent and 8.5 percent respectively of agriculture GDP (Figure 4).

In terms of strategic importance, maize comes first as it is the staple food. Livestock and livestock products contribute significantly to the economy of Zimbabwe. It is estimated that up to 60 percent of rural households own cattle, 70-90 percent own goats, while over 80 percent own chickens (MLAWFRD, 2018). The importance of livestock in rural livelihoods and food security lies in the provision of meat, milk, eggs, hides and skins, draught power, and manure. They also act as a strategic household investment. Small ruminants (sheep and goats) and non-ruminants, particularly poultry, are an important safety net in the event of drought – they are easily disposable for cash when the need arises or during a drought crisis (FAO, 2021). However, productivity and contribution of both crop and livestock are expected to go down as a result of climate change impact, even more so for subsistence farming and this may leave many depending on food aid. According to USAID (2019b), by 2050, the yields for maize and cotton in Zimbabwe are expected to decline in excess of 30 percent due to the impact of climate change.

Figure 4: Contribution of various agro sub-sectors to agriculture GDP (2018)



Source: MLAFWRD (2018)

Table 2 summarizes other key socio-economic indicators of Zimbabwe. It is clear that although per capita income has improved over time and the gap between agricultural exports and imports has increased in favour of exports, the number of poor people below the poverty line has remained significant and increasing. Values of total agriculture exports have been increasing between the period 2007 and 2019 from USD 809.3 million to USD 1.128 billion in 2019, whilst the value of agriculture imports ranges between USD320.3 and 1.16 billion between the periods under review (World Bank Development Indicators, 2022b). Areas under agriculture have remained constant between 2017 and 2019. The proportion of the population with access to electricity in the rural areas has increased to 20 percent and adult literacy levels (people aged 15 and above) have remained high (at over 88 percent for women and 89 percent for men).

The percentage of people actively employed in agriculture as the primary source of income have been increasing, however the proportion of women actively employed in primary production agriculture, declined from 71.69 percent in 2007 to 69.48 percent in 2019. The country has an estimated population of 14.65 million in 2019 with an increasing number of people , approximately 70 percent residing in rural areas (USAID, 2019b).

Table 2: Key socio-economic indicators of Zimbabwe

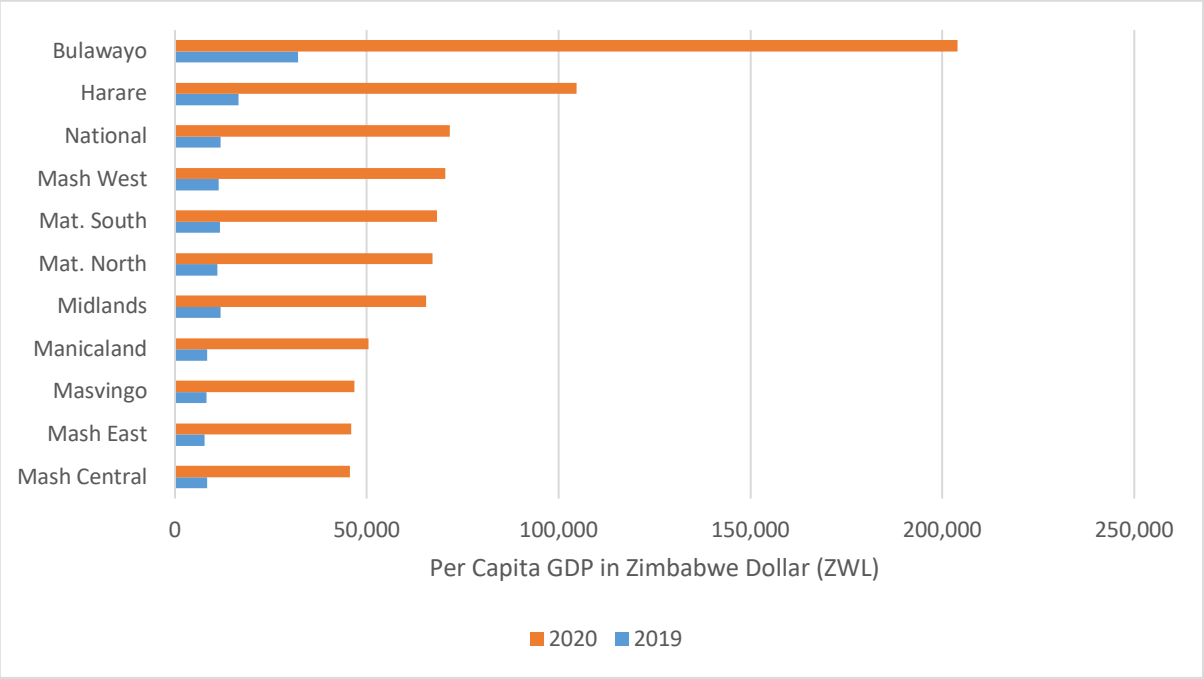
Indicator	2007	2009	2011	2013	2015	2017	2019
GDP per capita (2015 US$)	1,042.36	940.53	1,248.73	1,435.06	1,445.07	1,479.38	1,414.83
Contribution of agriculture to national GDP (%)	21.20	10.74	8.67	7.14	8.28	8.34	10.14
Value of total agricultural exports (US$) million	809.3	958.4	1,009.6	1,162.8	1,102.5	878.1	1,128.2
Value of total agricultural imports (US$) million	545.9	1,155.5	1,051.5	825.6	977.7	677.0	320.3
Agricultural area (sq. km)	162,000	163,000	164,000	162,000	162,000.	162,000	162,000
Agricultural area as a percentage of total land area (%)	41.88	42.14	42.39	41.88	41.88	41.88	
Total population in the country (million)	12.26	12.53	12.89	13.35	13.81	14.24	14,65
Rural population in the country (%)		66.62	66.99	67.35	67.62	67.76	67.79
People actively employed in primary production agriculture (%) (ILO Modelled Estimates)	65.5	66.1	65.9	66.8	67.1	66.5	66.2
Women actively employed in primary production agriculture, as a percentage of female employment (%)	71.69	72.32	71.65	71.68	71.29	70.25	69.48
Population living on less than US$ 1.90/day (%) [1]			5.20			9.30	13.40
Rural population with access to electricity (%)	11.26	19.58	14.08	15.56	10.95	18.64	20.05
Adult male literacy rate (%)			87.77		89.19		
Adult female literacy rate (%)			80.07		88.28		
Youth literacy rate (%)			90.93		90.43		
Gender Inequality Index			1.03		1.06		
Prevalence of people undernourished (%)							
Prevalence of children underweight (%)		11.70			8.50		9.7
Prevalence of children wasting (%)		2.40			3.30		

Source: World Bank Development Indicators, 2022b, FAOSTAT Database

GDP per capita by province

The composition of agricultural GDP by province shows low contributions from provinces such as Matabeleland North at 5.3 percent, Matabeleland South at 4.9 percent and Mashonaland Central at 5.8 percent. In Matabeleland the contribution of agriculture is very low, despite the high number of households involved in farming. This is mainly due to low productivity attributed the low annual rainfall received in the Province. As a result, communities in ths province are poor and more vulnerable to hockss as they have low income-generating activities (ZimStat, 2022). However, Bulawayo had the highest per capita GDP in Zimbabwe between 2019 and 2020 followed by Harare and Mashonaland West, whilst Mashonaland East and Mashonaland Central had the lowest per capita GDP in the reference period (ZimStat; 2022) (Figure 5).

Figure 5: Provincial Nominal Per Capita GDP in Zimbabwe dollars (2019-2020)

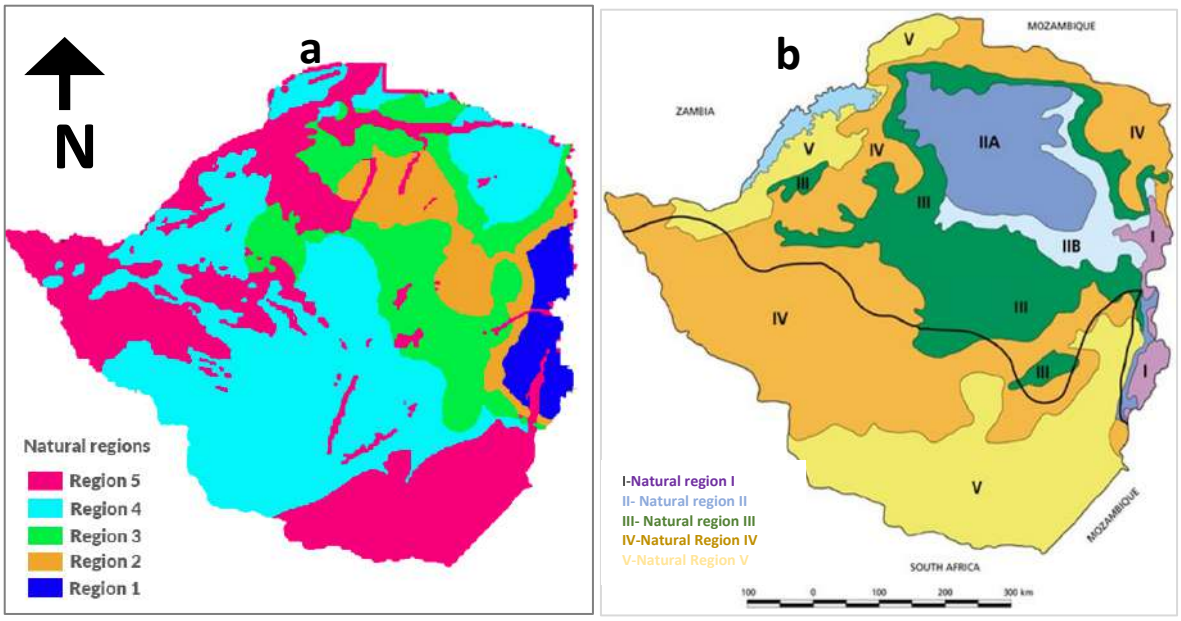


Source: Zimstat Provincial GDP 2019 to 2020

3.2. Main production systems

Zimbabwe is prone to a range of climate hazards that impact livestock and crop production, erode soils, damage crops and can lead to food insecurity and subsequently acute malnutrition. Crop and livestock production choices are strongly dictated by the country's natural agro-ecological regions, (which in turn are determined by the amount of rainfall, soil quality, vegetation and temperature) with natural regions 1 and II are the best for crop farming whilst natural region IV and V are drier and suitable for livestock and game ranching/ farming. The Zambezi River Basin is in natural regions IV and V which is susceptible to low rainfall and droughts. The livestock sector has been greatly affected by climate change especially in natural region V and IV , this is shown by increased livestock diseases such as January diseases (theorelolisis) and also increase in "poverty deaths" (deaths due to shortage of feed). According to USAID (2019b) there has been an increase in livestock deaths which are drought-related due to poor grazing and lack of water, thus with increased climate variability this will also likely impact the range, transmission rate and outbreak of certain livestock diseases.

Figure 6: Zimbabwe agro-ecological zones (a)as of 2012 and (b) as of 2022



Source: Government of Zimbabwe[2]

Rising temperatures and increasing rainfall variability, especially drought, are likely to accelerate declining crop production of highly sensitive crops, including maize, sorghum and millet, further compromising food security, economic growth and poverty. Maize is particularly vulnerable to rising temperatures and lack of precipitation; temperatures over 35°C result in lower yields (USAID, 2019). Matarira et al. (2004) established that yields of maize, decreased dramatically under dry land conditions in some regions (up to 30percent) even under full irrigation conditions because of increasing g temperature that shorten the farming season. The area suitable for maize cultivation is predicted to decrease by over 40percent by 2080, while suitable areas for cotton and sorghum will increase by more than 30percent by 2080. In addition to these challenges to food security, changes could create conditions more conducive to the increased spread of new agricultural pests, posing threats to key staple crops and livestock, specifically maize and sorghum.

Climate change will severely impact on the country's water resources. High levels of runoff have contributed to erosion and siltation of rivers and dams hence reducing flow and water holding capacity. Reduced river and stream flows would also curtail hydroelectricity generation , which contribution to national power production was 51.4 percent in 2014 (Brazier, 2015). Hydropower, which forms the bulk of electricity production for Zimbabwe is under threat as a result of increased siltation of both the Zambezi River and Kariba dam severely affecting electricity generation and may culminate in increased deforestation as people resort to alternative biomass fuel.

A report by the World Bank (2018) predicated that climate change is likely to cause an annual rainfall decrease in all Zimbabwean catchments, except Mazowe and Manyame. The largest decline will be in the Runde and Mzingwane catchments where average rainfall could decrease by between 12 and 16 percent by 2050. The decrease in water availability will affect irrigation for agriculture, energy generation for mining, manufacturing and commerce, and tourism and human health. Even with a best-case scenario, there is likely

[2] https://reliefweb.int/sites/reliefweb.int/files/resources/7BFF49F0B55F020085257664007D5442-map.pdf Factsheet: Climate change redraws Zimbabwe's agro-ecological map ;https://zimfact.org/factsheet-climate-change-redraws-zimbabwes-agro-ecological-map/https://zimfact.org/factsheet-climate-change-redraws-zimbabwes-agro-ecological-map/

to be a 38percent decline in national per capita water availability by 2050 (World Bank (2018). Urban and rural communities in the south and west of Zimbabwe could be seriously affected by water stress. The report also notes that climate change will cause increasing dependence on groundwater sources in Zimbabwe and the management of groundwater, therefore, needs to be improved.

As drought and high temperatures coupled with poor catchment practices such as deforestation being experienced now will likely exacerbate water shortage for agriculture and domestic purposes. This results in reduced yield, crop failure and food insecurity for smallholder farmers. Zimbabwe could fall into the United Nations' "absolute water scarcity" category" by 2080 (Brazier, 2015) as a result of the increasingly erratic nature and unreliability of the rainy season coupled with medium or high population growth. Climate Change in Zimbabwe has resulted to new agro-ecological zoning as shown in Figure 6 (a) and 6 (b) above.

3.3. Mapping of existing initiatives relating to digital technologies and climate adaptation

3.3.1 Digital Adaptation in agriculture

According to ICRISAT (2022), Digital Agriculture is Information Communication Technology (ICT) and data ecosystems to support the development and delivery of timely, targeted information and services to make farming profitable and sustainable while delivering safe nutritious and affordable food for all. ICT infrastructures are all the information and communications technology and systems (including software, hardware, firmware, networks, and company websites) that can be used to improve communication and preparedness. These include remote sensing for monitoring natural disasters such as floods and improved communications to help deal with climate shocks and hazards by providing early warning information, crop condition, and disease outbreaks such as armyworm which is prevalent in the Zambezi basin allows stakeholders to act. Digital technologies, and satellite and surface-based remote sensors, in particular, are tools for environmental observation, climate monitoring, and providing data for climate change prediction on a global basis.

Due to challenges associated with the COVID-19 pandemic, digitalization of the agriculture sector became imperative as it enables continuous production in the face of labour shortage, access to information and extension services, and access to the market through e-agriculture platforms. There was limited physical intercations between farmers and extension officers, however they were able to interact more virtually through phones and social media platforms such as Whatsapp.Advances in machinery have expanded the scale, speed, and productivity of farm equipment, leading to more efficient production practices including the use of planting equipment, land preparation, irrigation, and fertilizers application, access to inputs and finance also have vastly improved, helping farmers to increase profitability along the value chain. Digitalization of the agriculture sector addresses social inclusion gaps for youth, women, and other marginalized groups, which is critical in improving community resilience considering women and forms the majority of the labour force in rural areas.

To scale-up and scale-out climate-smart products and services, a Econet Wireless Zimbabwe, a private sector telecommunications company has teamed up with a leading farmers' organisation in Zimbabwe to promote digital technologies for climate change adaptation. The mobile technology solutions, which delivers weather-based insurance, location-based weather information in real time, and farming tips via cell phone, is helping producers to combat the effects of climate change through improved preparedness. The delivery channel to the cellphone is through SMS . There has been a lot of work that has been put into fixed communications networks anchored on optic fibre, copper and radio communication such as CDMA based (fixed-wireless) telecommunications services. The expansion of 3G,4G, 5G and LTE-based mobile broadband services has increased internet access and availability. The National Development Strategy 1 of GoZ prioritizes infrastructure development including transport (road, rail and air) and irrigation targeting both surface and groundwater. ICTs rely on a ubiquitous power supply, hence the absence and erratic

power supply in the country affects the geographical spread of ICTs. Investment into renewable energy such as solar is being explored to meet the energy demand, especially with the digitalization of the agriculture sector. Examples of these digital technologies highlighted as key in climate change adaptation in the agricultural sector are given in Table 3.

Table 3: Examples of digital technologies

Nature	Technologies for directfarmers support	Technologies for farmer support system (Indirect)	How they support Climate Change Adaptation
Digital technology	Communication systems such as digital apps and SMS	Communication systems such as digital apps and SMS	Help in providing early warning information
	Community radios and Televisions, Websites, Blogs and Social Media;	Community radios and Televisions, Websites, Blogs and Social Media;	
	• Buying and Selling Online/E-Commerce/E-Markets;	Buying and Selling Online/E-Commerce/E-Markets;	Reducing GHG emission from transport to the market and also use of paper
	Smartphones; Cameras; Clocks	Smartphones; Cameras; Clocks	
	• Video Streaming & Digital Music; EBooks;	• Video Streaming & Digital Music; EBooks;	Reducing GHG emission from transport to the market and also use of paper
	• GPS and GIS;	• GPS and GIS;	Critical in mapping areas that are vulnerable to climate change and also in developing mitigation strategies
	• Computers, Printers and Self-Scan Machines;	• Computers, Printers and Self-Scan Machines;	Useful for climate data analysis, projections as well as communicating climate releted information
	• Robotics and Drones ; and E-Mobility	• Robotics and Drones	Critical in mapping areas that are vulnerable to climate change
	• Block chain	• Blockchain	Reduces paperwork hence reduction in GHG emissions
Infrastructure	• Automated Teller Machines (ATMs)	• Automated Teller Machines (ATMs)	Reduces paperwork hence reduction in GHG emissions
		• Telecommunication Base stations	Help in the dissemination and provision of early warning information
		• Radio and Television transmitters	
		• Fibre Optic cables and Roads	
		• Electricity Grids	Provision of energy critical in the use of climate change adaptation technologies

		• Banking and Finance application	Reduces paperwork hence reduction in GHG emissions

Source:: Project Consultative Workshop, Zimbabwe (2022)

3.3.2 Digital agricultural services and applications available

The presence of a high number of operators ensures a competitive environment that will ensure the provision of quality services. Zimbabwe has made digital advancements, including a revolution in mobile money, resulting in about 7.1 million mobile wallet holders in a country of just over 15 million(World Bank; 2019). Zimbabwe has a relatively well-developed digital payment system, where 96percent of all transactions in the country's formal sector are conducted through digital means and only 4percent are cash-based, and the Government uses digital money almost exclusively (Reserve Bank of Zimbabwe; 2022). However, even with these advances, Zimbabwe is currently capturing only a fraction of its digital transformation growth potential, therefore there is a need for strategic investments in digital skills and infrastructure, as well accelerate the creation of digital platforms and digital entrepreneurship to create the foundations for the digital economy of the future (CGTN Africa.2021).

The government through various line ministries is rolling out the digitalization program through programs such as e-Government services, online service delivery, e-public services, e-revenue and one-stop service, or integration of all Government services to citizens and businesses. Due to the COVID-19 lockdown restrictions, these platforms allowed virtual interaction hence playing a big role in reducing the spread of COVID-19 and continued access to resources and services. Whilst these tools have been very useful there is a need to raise awareness such that the adoption of digital technologies can be scaled up. Discusions during the stakeholder conference. The main challenges in the adoption of digital tools in communities such as those in the Zambezi basin identified during the stakeholder workshop included the following: limited awareness, lack of digital skills, and the poor digital infrastructure that results in some areas having limited connectivity

Table 4 summarize some of the digital technologies initiated and promoted by the government, development partners and the private sector;

Table 4: Digital Technology initiatives

Digital initiatives by Government	**Digital initiatives by Development Partners and Private sector**
Early Warning Systems **https://fews.net/southern-africa/zimbabwe** **E-Agriculture, E-Irrigation, E-Extension, E-Commerce,** Community Informations Cemtres (CIC) (**http://www.zarnet.ac.zw/index.php/community-information-centres/#:~:text=ZARNet%20in%20partnership%20with%20the,of%20life%20in%20rural%20Zimbabwe**) Precision and Climate Smart Agriculture. **https://www.sirdc.ac.zw/institutes/biotechnology-research/** Automated weather stations	E-Marketing, https://ownaimarketplace.co.zw/ Social Media platforms, blogs and websites Agrishare, (https://www.agrishare.app/) Kurima Mari (https://play.google.com/store/apps/details?id=zw.co.kurimamari&hl=en&gl=US) Eco-farmer(https://www.ecofarmer.co.zw/) and Eco cash Platforms (https://www.ecocash.co.zw/) Computers, printers Digital cameras One Money (https://www.netone.co.zw/products/view-product/109-onemoney), Tele-cash (https://telecel.co.zw/telecash) .

Geographical Infomation System (GIS) (https://www.sirdc.ac.zw/institutes/geo-info-remote-sensing/) Radios and Television stations (https://www.zbccorporate.co.zw/) Innovation hubs meant to strengthen ties between universities and the private sector, while serving as incubators for innovations created by students, faculty and researchers.	

Source: Authors' Illustration

The commonly used ICT in agriculture include mobile and smartphones, television, community radio, text-based messaging, mobile weather applications for smartphones, websites, social media, geographic information system (GIS) and satellite imagery (Sarku et al., 2021). These digital tools for adaptation are not without challenges as discussed below.

Table 5: Technology and adaptation challenges

Technology	Challenges
Social media	Social media requires advanced ICTs such as applications and smartphones, not accessible to all farmers. The unavailability of the internet and other infrastructures can be challenging, farmers' inability to navigate several ICTs and read messages. There is also little local content and guide on the application of information.
Mobile weather applications for smartphones	The challenges include low levels of smartphone ownership, especially in rural areas, mobile data is expensive, unavailability of the internet in some areas, the inability to use a smartphone, complexity attached to navigating applications and many farmers are smartphone phobia due to language and literacy barrier.
Smartphones	Challenges include the difficulty in swiping sensitive screens, switching data and renewal of internet data, high cost of internet bundles, inaccessible internet in most rural areas, and the technology is not coded in the local languages.
Websites	Websites offer limited opportunities for interactions. Limited internet access affects its use in many rural areas, and farmers find it difficult to read and interpret information by themselves because of limited literacy levels.
Short messaging services (SMS)	SMSs have many challenges including the deductions debited from call credit, and SMS nuisance due to numerous messages from telecommunication networks. Information is mostly delivered in English, making it difficult for some farmers to understand. Additionally, the lack of graphic communication and too short messages sometimes lead to inadequate comprehension of information. Lack of interactions and a lack of outlook forecast for the day are other challenges.
IVR and USSD	Information is mostly delivered in English, making it difficult for some farmers to understand. Additionally, the lack of graphic communication and rigid responses which are not flexible to farmers queries sometimes lead to inadequate comprehension of the information.
Mobile phone	Access to messages are at a fee which may deter farmers from accessing them. Also, illiterate farmers cannot read and understand messages delivered in the English language while novice users cannot trace or navigate through the phone to trace missed calls. Loss of phone may result in permanent loss of messages and implies a cost for the purchase of a new phone.
Television	The main challenges with television include the lack of interaction with viewers. Information access is affected by the unavailability of electricity, weak network signals and poor reception in some areas and unfamiliarity with symbols depicting weather conditions such as rainfall and sunshine.
GIS	Some of the major challenges with GIS include the cost of acquiring the software as it may be expensive. understand technical information/ouputsfor .Using GIS entails having another ICT such as a computer, which increases the cost of using the application.

Source: Author's illustration

4. Climate Risks Vulnerability and Resilience

4.1. Zimbabwe's Climate in brief

The country is increasingly facing risks emanating from climate change, worsened by COVID-19 and an unstable macro-economic environment exacerbating poverty, food insecurity, and malnutrition, especially among smallholder farmers (USAID, 2019). As climatic conditions in Zimbabwe become more erratic, high temperatures coupled with degraded land and smallholder farming contributing towards widespread crop failures occurring every three out of five years, food and nutrition insecurity among the rural population is expected to remain.

Zimbabwe has a primarily semi-arid climate characterized by its topography of a high central plateau (called the "Highveld" and a high watershed that sits between 1,200 to 1,600 metres above sea level and experiences a subtropical climatic condition. The hot, dry Kariba Valley and a series of mountain ranges line the country's eastern boundary. The lowlands (called the "lowveld") include the major low-lying river valleys of the Zambezi in the north and the Limpopo River in the south have a tropical climate. Zimbabwe's climate is subtropical with four seasons: cool season from mid-May to August, hot season from September to mid-November, main rainy season from mid-November to mid-March with relatively high temperature and the post rainy season from mid-March to mid-May. Mean annual rainfall ranges from 300 mm in the south-western region to over 1,000 mm in the north-eastern region of the country. The equatorial, tropical rain belt, the Inter-tropical Convergence Zone (ITCZ) also brings more rainfall during the southern hemisphere winter, and less when it migrates north. On average, southern Zimbabwe receives less rainfall (300–500 mm) than the northern (700–1000 mm) and the eastern (above 1000 mm) parts of the country (Government of Zimbabwe, 2016a). The western part of Zimbabwe is generally arid, with little potential for dam sites because of the nature of soils, low rainfall, and generally flat topography.

4.2. Sensitivity of the country to shocks

Zimbabwe, climate change will cause average temperatures to rise by about 3°C before the end of this century (USAID, 2019). Annual rainfall could decline by between 5 percent and 18percent, especially in the south (USAID, 2019). Rainfall will become more variable. There will be an increase in droughts, floods and storms. Zimbabwe is vulnerable to climate change principally through shifting rainfall patterns and extreme events. Increased incidence of drought is expected to be a particular problem. Other potential changes include increased temperatures, localized floods and decreased/varying river flow.

As per another prediction, all districts in Malawi, Zimbabwe and the whole of Zambia except parts of the Northern Province will be hotspots of climate variability and extreme weather events by 2050 (Cairns et al., 2013; Davies, Midgley and Chesterman, 2010). Climate hazards such as severe droughts and flash floods are anticipated to be more frequent and intense in the coming decades in Zimbabwe (Davies, Midgley and Chesterman 2010). Manyeruke, Hamauswa, and Mhandara (2013) show that drought prone regions, natural regions 4 and 5 had become drier while increased in area by about 6percent and 23percent. Major food producing regions, NR II and III, had shrunk remarkably by 49percent and 14percent respectively (ibid). Similar changes have also been reported by Mutasa (2019). The changes experienced indicate that the country is moving towards more arid and non-arable climatic conditions, which could potentially lead to food insecurity and vulnerability.

Coupled Model Inter-comparison Project Phase 5 (CMIP5) utilized within the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) provide projections of future temperature and precipitation of Zimbabwe. These models project consistent warming that varies by emissions scenario; meanwhile projected trends in rainfall are less certain, varying widely across both scenarios and models

(GoZ, 2016). Accordingly, the annual likelihood of encountering severe drought in Zimbabwe is projected to increase by 21percent in 2040 to 2059 and by 47percent in 2080 to 2099 compared to the baseline period of 1986 to 2005 under the RCP8.5 scenario (USAID, 2019). It is projected that western Zimbabwe is more likely to experience drought conditions. Extreme temperatures and precipitation events will be more prominent in the country. The number of days/years with a maximum temperature greater than 35°C is expected to increase by 39 days in the period from 2040 to 2059 and 108 days in 2080 to 2099 from the reference period under RCP8.5. The number of days of the consecutive dry spell per year (or days without significant rainfall of at least 1mm) is projected to increase by 13 days in 2040 to 2059 and 25 days in 2080 to 2099. Climate change is expected to negatively impact the future occurrence, intensity and magnitude of floods, droughts, and epidemic episodes, which can consequentially lead to enormous social and economic costs across multiple economic sectors (GoZ, 2016a).

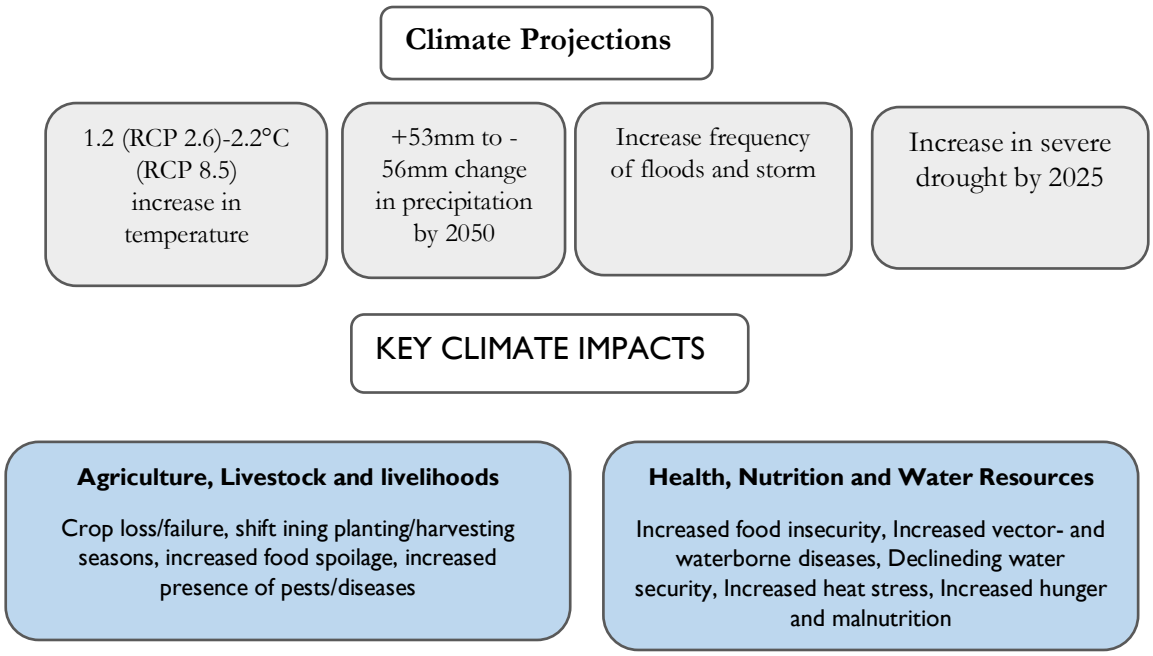
USAID (2019) summarizes the projected climate change features of Zimbabwe as follows based on World Bank 2019; Mtetwa 2018; UNDP 2017; and GoZ 2016b.

- Increase in temperature of 1.2–2.2°C between 2040 and 2059
- Increase in days with maximum temperatures >35°C by 39 days between 2040 and 2059
- More variable precipitation, with some models projecting an increase in the long term, and others projecting a decrease
- Increased rainfall in the north and east; reduced rainfall in the south and west
- Dry spells lasting 13 days longer than the average current duration between 2040 and 2059
- 21 percent increased incidence of severe drought between 2040 and 2059

Due to climate change, Zimbabwe like most Southern African countries has been facing a lot of climate change related risks. Climate risk is the degree to which a system is susceptible to and unable to cope with adverse effects of climate change including climate variability and extremes (IPCC, 2021). Over the last few decades, Zimbabwe has experienced high temperatures and increasingly variable rainfall, with little change in annual rainfall but with more extreme events (i.e., longer, more frequent dry spells and fewer, more intense rain days). Studies have found that climate change has caused some regional shifts to drier agro-ecological zones which could impact livelihoods, especially where people have limited resources and information with which to adapt to new conditions. Small-scale farmers have already been affected by changing climate conditions over the last few decades and these climate trends are predicted to continue. Based on EM-Dat data base from 1900 to 2017, there were 7 droughts, 22 epidemic occurrences, 12 floods, and 5 storms in Zimbabwe, which resulted in total deaths of 7000 people with more than 20 million people affected, causing estimated total damage of USD 950 million. Zimbabwe has experienced negative impacts associated with climate variability and change in agro-ecological zones, especially in the past decades such as a significant increase in the frequency and severity of extreme events droughts and flash floods (Mudombi 2013).

Some of the major climate change risks facing the Zambezi basin are described in Figure 7.

Figure 7: Climate projections and key climate impacts



Source: USAID (2019); * RPC- Representative Concentration Pathways,

4.3. Droughts and floods

Drought is defined as a deficiency in precipitation over an extended period, usually a season or more, resulting in water shortage, causing adverse impacts on vegetation, animals, and/or people. Drought is a recurrent feature of climate change that occurs in virtually all climate zones, from very wet to very dry. In Zimbabwe, drought has caused six of the 10 worst natural disasters between 1991 and 2013 (MLAFWRD, 2021). Much of Zimbabwe is comprised of semi-arid agro-ecological regions IV and V, characterised by low and erratic rainfalls and poor soils. Given Zimbabwe's heavy reliance on rain-fed agriculture and livestock, drought has serious implications on food security and livelihoods. Drought also impacts on water availability for domestic and industrial use and Hydropower generation affecting cities and non-agriculture sectors.

Floods occur more frequently, usually every year, and often as a result of cyclones. Recent records also show an increase in violent storms with hail and strong winds which damage infrastructure, property and crops and cause loss of life (i.e., human and livestock). Floods tend to occur in the southern and northern low-lying areas of Zimbabwe, in the paths of cyclones, in between river confluences and downstream of major dams. The frequency of floods and droughts is increasing in Zimbabwe as a result of climate change.

Erratic rains, drought, mid-season dry spells and other negative effects on agriculture combined to cause crop and livestock price changes. The prices changes are often a threat to livelihoods since they lead to unaffordability of food when they are high and a reduction in income when they are low. Another set of climate risks of note are the crop pest and diseases due to their effect of reducing yield in affected areas.

Cyclones have not been very frequent in Zimbabwe in the past, but over the last decade, Cyclone Idai (2019), Cyclone Japhet (2003) and Cyclone Eline (2000) affected millions of people in the east and southeast of the country and in the Zambezi basin in the north. Damages induced by cyclones include the destruction of roads, bridges, dams and houses.

Episodes of high temperatures such as heat waves are becoming regular. During the droughts, dry spells and extremely high temperatures are experienced, worsening the heat and moisture stress on humans, flora

and fauna. Water losses through evapotranspiration are very common as a result shallow water sources dry up and the water table lowers resulting in reduced access to water for crops, humans and livestock.

4.4. Pasture management, soil degradation and increased pests and diseases

Lack of pastures in certain areas due to frequent droughts which contributed to the continuous deterioration of pastures in terms of quantity and quality. Drought makes it difficult for pastures to replenish hence affect the production and productivity of the livestock sector. Drought makes replenishment of the pastures slow while floods wash away the topsoil which is critical for plant growth. Some districts have experienced more animal disease outbreaks in the past 10 years compared to the period 1980-2000. The most common diseases among domesticated herbivorous animals include lumpy skin, rabies, diarrhoea, heart water, anthrax, and foot and mouth disease (FMD). For poultry, new castle and coccidiosis are the major ones identified by the Veterinary Services (MLAFWRD, 2021). This is based on the areas affected in any given year as well as the severity of damage during the drought and floods. Rural Zimbabwe remains vulnerable to these diseases due to limited resources for coordination, information, vaccination and awareness campaigns.

Another climate risk suggested by stakeholders during consultations is the increase in diarrheal diseases among the people. The records reveal a number of outbreaks every year during the floods which affect agricultural production and, in some cases, lead to mortality. Increases in the incidence of diseases such as diarrhoea, malaria, and cholera as a results of reduced water quality, temperatures and flooding and cholera due to increased flooding. Diarrheal diseases include common diarrhoea, typhoid, dysentery, and cholera. The main causes of diarrheal diseases are limited water and sanitation facilities. One of the worst outbreaks occurred in 2008 when over 11 000 people were affected by cholera countrywide.

Due to poor catchment management practices such as deforestation, there is increased siltation of major water bodies and rivers in Zimbabwe including Save and Zambezi rivers and the Kariba dam. Siltation reduces their water holding capacity, contributes to water loss and increased the risk of flooding. . The amount of water available for commercial and domestic purposes is reduced as the water is lost through increased runoff. Due to strong winds and hailstorms, there has been an increase in property destruction, crops and livestock due to climate risk.

Table 6 summarises some of the major impacts of climate change from 1973 to 2021. In general, all the years were negatively affected by either floods or drought with varying intensities.

Table 6: Summary of notable flood and drought events, 1973 - 2021

Period	Condition
2020-2021	Floods in some parts of Zimbabwe due to excessive rainfall.
2018-2019	Floods in parts of Malawi, Mozambique and Zimbabwe due to Cyclone IDAI
2017	During January and February, many parts of Southern Africa including parts of the Zambezi watercourse experienced very severe seasonal rains and, in February, Tropical Cyclone Dineo made landfall near Inhambane, Southern Mozambique. These caused losses of life and property in Mozambique, Malawi, Zimbabwe, Botswana and Namibia
2015-2016	Drought linked to the EI Nino Southern Oscillation climate phenomenon reported to be the worst in the past 35 years, affecting 39 million people, about 13% of SADC
2014-2015	Tens of thousands of people in Malawi Mozambique and Zimbabwe were severely affected by floods caused by tropical storm Chedza, which started in December and continued through February 2015. Malawi was hard hit by the floods. More than 200 people died and 500 000 were displaced. In Mozambique 150 000 people were affected and about 6 000 in Zimbabwe
2012-2013	Following a poor performance in November, good rains were received in the first 10 days of December, but dry conditions resumed in late January through to May in the southern parts of the Zambezi Watercourse
2008-2009	The watercourse experienced flooding, which displaced thousands of people in Angola, Botswana, Malawi Namibia and Zambia.
2007	Floods induced by Cyclone Favio impacted Mozambique and part of Zimbabwe
2005-2006	Parts of southern Africa received very heavy rains resulting in flooding that caused considerable infrastructural damage, destroying schools, crops, roads and telecommunication lines.
2004-2005	Many parts of the Zambezi watercourse received below-normal rainfall during the agricultural season. Several members' states also declared a national disaster.
2001-2003	Severe drought in the SADC region
1999-2000	Cyclone Eline hits the region and widespread floods devastated large parts of the Limpopo basin (Southern and central Mozambique alone this affected 2 million people with 650 000 forced to abandon their homes.
1991-4-1995	Many countries in the SADC region were hit by severe drought, surpassing the impact of the 1991-1992 drought.
1991-1992	The worst drought in living memory was experienced in southern Africa, excluding Namibia.
1986-1987	Drought condition return to the region.
1983	This year saw a particularly severe drought for the entire African continent.
1982	Most of the sub-tropical countries experienced drought.
1981-1982	Severe drought occurred in most parts of Southern Africa.
1967-1973	This six-year period was dry across the entire region. Some records show a severe drought.

Source: IPCC, 2021

4.5. Other Challenges facing smallholder farmers due to climate change

- **Veld fires**

Veld fires have emerged to be one of the greatest environmental challenges in Zimbabwe. Over the years, an average of a million hectares is burnt each year, resulting in loss of pasture, forest resources, plantations, livestock, property e.g., homes and farming implements and sadly human lives. This disturbs the natural ecosystem and hence the natural life cycle and the water cycle.

- **Impact on production systems**

Climate change is impacting negatively on all production systems, however, smallholder production systems which depend on rain-fed agriculture are affected the most as a result of crop failure, loss of productivity, increasing food insecurity and vulnerability. Strategies need to be put in place to ensure the negative impacts of these climate risks are mitigated. The use of digital technologies is one of the ways to mitigate climate risk.

5. Digital Adaptation to Climate Change

Most digital technologies rely on energy for their operations, there is a need to address energy issues as an enabling environment for the adoption of these technologies. Lowering the cost of tools such as phones and sim cards present opportunities for scaling digitalization through improved access to information. However, sound investment is still needed for ICT infrastructure upgrading and improving coverage in areas that are not well serviced. There is a need for funding research and development for locally produced digital tools, this may reduce the cost of technologies such that more people can access these tools, especially women.

5.1. Government Ministries spearheading adaptation

The Government is promoting climate change adaptation through various policies such as National climate policy, National climate response strategy, National development strategy, National determined contribution, National adaptation plan, National climate change learning strategy and the Sustainable development goals. The Government of Zimbabwe and private partners are promoting preparedness through various strategies including digitalization. Digital technologies have been very instrumental in supporting farmers' right decision making on time based on information received so as to improve preparedness in the face of climate hazards. Data generating tools such as early warning systems have been used to map the impending disaster for example drought and the messages are being conveyed through digital tools such as mobile phones, radio, TVs, newspapers, social media platforms and as a result, this has improved disaster preparedness. Farmers have also been getting weather and market information. Through use of community radios, which use local languages has helped farmers understand the messages such that where possible they go and implement the recommendation, hence improving adaptive capacity.

Climate change adaptation is a cross-cutting issue involving stackholders from both the public and private sector.. In Zimbabwe the key actors included in climate change adaptation are:

i. Ministry of Lands, Agriculture, Fisheries, Water and Rural Development, responsible for the promotion and sustain a viable agricultural sector through the provision of appropriate agricultural infrastructure, mechanisation, technical, administrative and advisory services in order to optimize agricultural productivity to ensure food security. This also includes digital technologies for climate change adaptation.
ii. Ministry of Environment, Climate and Hospitality Industry responsible for the management, conservation and promotion of sustainable use of natural resources. The National Climate Change policy is administered by this Ministry including adaptation strategies.

iii. Ministry of ICT Postal & Courier Services responsible for the development of appropriate policies and strategies and creation of an enabling environment that enhance provision of ICT, telecommunications, postal and courier services in Zimbabwe.
iv. Ministry of Finance and Economic Development; is entrusted with the stewardship of national resources, their mobilization, allocation, management and accounting for economic growth and development through the provision of sound macro-economic policies
v. Ministry of Local Government; The Ministry of Local Government is mandated to promote sound local governance, undertake and coordinate rural and urban development as well as coordinating the national Disaster Risk Management through the Civil Protection Unit (CPU)
vi. Private sector players such as telecommunication companies, agriculture manufacturing and irrigation companies among others responsible for provson of services for a fee;
vii. Development partners responsible for supporting government and the private sector in the provison of public service and disaster management; and
viii. Civil society organizations to raise awereness and hold government to account on developmental issues related to climate change and disaster management. They also pilot digital technologies before adoption and upscaling of these technologies.

Implementation of the policies and strategies is done by the different stakeholders complimenting each other. This is to avoid resource wastage due to duplication. Table 7 summarizes some of the major policies and legislation which support use of digital technologies in climate change adaptation.

Table 7: Policies that promote climate change digital technology in climate change adaptation

Sector	Policy	Comment
Agriculture and food security	Zimbabwe National Policy for ICT 2016 http://www.veritaszim.net/sites/veritas_d/files/Zimbabwe%20National%20Policy%20for%20ICT%202016.pdf	Promote the adoption of ICT based agriculture including adaptation and early warning
	National Climate Policy (https://climate-laws.org/geographies/zimbabwe/policies/national-climate-policy#:~:text=The%20National%20Climate%20Policy%20aims,to%20rural%20communities%20and%20agriculture .) National Climate Response Strategy (http://ncuwash.org/newfour/wp-content/uploads/2017/08/Climate-Change-Response-Strategy.pdf) National Development Strategy 1 (http://www.zimtreasury.gov.zw/index.php?option=com_phocadownload&view=category&download=336:national-development-strategy-presentation-nds1&id=64:national-development-strategy-1&Itemid=789) Nationally Determined Contribution (NDCs) (https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Zimbabwe%20First/Zimbabwe%20Revised%20Nationally%20Determined%20Contribution%202021%20Final.pdf) Agriculture and Food Systems Transformation Strategy	Support climate-smart agriculture which promotes climate change adaptation Promote the use of digital technologies in climate change adaptation
	Low Emission Development Strategy (http://www.envirotourism.org.zw/wp-content/uploads/2017/08/Zimbabwe-Low-Emissions-Development-Strategy-LEDS.pdf)	Promote the use of technologies in reducing GHGs, use of technologies in measuring GHGs emissions, Early Warning Systems

	National Adaptation Plan (https://napglobalnetwork.org/wp-content/uploads/2019/04/napgn-en-2019-nap-roadmap-for-zimbabwe.pdf) National Climate Change Learning Strategy (https://www.uncclearn.org/wp-content/uploads/2021/03/NCCLS.pdf)	
	Sustainable Development Goals (SDGs)	Advocate for sustainable agriculture production methods which are climate friendly
	Meteorological Services Act of 1990, (https://www.law.co.zw/download/meteorological-services-act/) and the National Policy and for Drought Mitigation (https://www.unccd.int/sites/default/files/country_profile_documents/1%2520FINAL_NDP_Zimbabwe.pdf)	Promote the use of digital technologies in weather forecast, Early Warning Systems, Disaster Risk Reduction
Water	Act of 1998 and National Water Policy (http://ncuwash.org/newfour/wp-content/uploads/2017/08/National-Water-Policy.pdf), A National Water Resources Master Plan for 2020–2040 (NWRMP)	Promote digital technologies in irrigation which conserve water
Energy	National Energy Policy (2012) (https://climate-laws.org/geographies/zimbabwe/policies/national-energy-policy-a763ee71-74cc-47ca-9057-6762230197b6) . Climate Change Response Strategy (2015)	Digital technologies to monitor GHGs, EWS
Forestry	The Forest Act (1999) (http://forestry.co.zw/wp-content/uploads/2017/03/FOREST_ACT_19_05-1.pdf) Communal Lands Forest Produce Act (1987) (http://forestry.co.zw/wp-content/uploads/2017/03/COMMUNAL-LAND-FOREST-PRODUCE-ACT-CHAPTER-1904.pdf)	Digital technologies to monitor deforestation, siltation levels, tensor meters
Disaster Risk Management	Bill under the Civil Protection Act of 1989 https://www.climate-laws.org/geographies/zimbabwe/laws/civil-protection-act , Capacity for Disaster Reduction Initiative (CADRI) in 2017	Digital Technologies on EWS,
Finance	National Budget (http://www.zimtreasury.gov.zw/index.php?option=com_phocadownload&view=category&id=13:appropriation-acts&Itemid=790 / http://www.zimtreasury.gov.zw/index.php?option=com_phocadownload&view=category&id=14:finance-act&Itemid=788	Have incentives and tax incentives for manufacturers, importers and consumers of digital technologies, have policies that promote or hinder adoption of digital technologies

Source: Authors compilation

5.2. Support for digital adaptation

Digital adaption process requires investments in ICT infrastructure to improve coverage and upgrade current infrastructure especially in those areas such as the Zambezi basin that have poor coverage. These investments can be used to source equipment to capacitate the early warning departments such as the civil

protection unit and their metrological service department. These processes require a multi-sectorial collaboration from an effective implementation process. Financing of the digital adaption process requires increased budget allocation from the treasury, macroeconomic stabilization that promotes foreign direct investments. The private sector can play a key role in improving access to digital tools, the Government can promote this through subsidies and tax rebates.

Non-Governmental Organization (NGOs) have been actively involved in supporting the digitalization process for example Environment Africa gave out radio units to farmers to improve access to information. Zimbabwe has quite a big population in the diaspora, and they can also take part in scaling the access to digital adaptation technologies and the infrastructure to support it. For example, at the household level, someone in the diaspora can invest in the solar system or irrigation for their family. Farmers through awareness program can choose to adopt climate smart agriculture as a way to ensure food security for the family.

The potential funding sources are the Government, Development partners, and public-private partnerships among others. The partnership between the Government and private players such as Econet wireless on the Eco farmer application enabled farmers to access information, carry out transactions and rollout weather index insurance using the virtual platform, especially during the COVID-19 restrictions. The EcoFarmer Weather Indexed Insurance (WII) provides provides smallholder farmers with cover for potential loss due unpredictable cycles of droughts and excessive rainfall . The insurance currently covers maize production and is available for farmers under natural farming region 1, 2 and 3.Farmers pay a premium of 10% e.g. $2.50 for $25 cover per season[3]. Whilst these tools have been very useful there is a need to raise awareness such that the adoption of technologies can be scaled up. The main challenges in the adoption of digital tools in communities such as those in the Zambezi basin are limited awareness, cost of digital tools, lack of digital skills, and the poor digital infrastructure that results in some areas being badly serviced as shown by the presence of grey areas where access to the network is limited. This should be coupled with digital literacy such that the full benefit of the technologies can be fully realized.

Research and development are key in developing digital technologies that best meet the needs of the people in Zimbabwe. The Government through the Department of Research and Specialist Services (DR&SS) in partnership with various partners such as academia, non-governmental organizations have been involved in research focusing on finding solutions to the adaptation challenges faced by smallholder farmers. Support towards digital adaptation in Zimbabwe includes interventions by the organisations listed in Table 7 (page 23). Most of the programmes aim to build both institutional and individual capacities to adopt, adapt and transform in the event of a shock or stress.

Composite flood and drought indicators are currently used to review multiple risks, and inform early warning and early action strategies. Using approaches such as the Integrated Drought Severity Index (IDSI) and the National Drought Risk Index (NDRI) allows countries to assess their drought risk. The Integrated Drought Risk Management framework is used for

a. Vulnerability and impact assessment;

b. Establish Monitoring and early warning systems (EWS); and

c. Prepare actions for Mitigation, preparedness and response.

According to Integrated Drought Risk Management Framework, Zimbabwe's vulnerability and impact assessment capacity is categorized as medium. Zimbabwe's capacity in drought monitoring and EWS, is also classified as medium, as currently the national structures set up to facilitate drought monitoring and

[3]The EcoFarmer Story; https://www.ecofarmer.co.zw/about; EcoFarmer Weather Indexed Insurance (WII); https://www.ecofarmer.co.zw/financial-services/ecofarmer-weather-indexed-insurance accessed 16 May 2022

EWS are in place but lack the technical capacity and financial resources to fully operationalize it, relying heavily on external structures such as the SADC Regional Early Warning Unit and the USAID-funded Famine Early Warning System (FEWSNET) (SADRI; 2021)). Additionally, while drought monitoring has received increased attention in Zimbabwe, the drought hazard in the country is quantified largely with precipitation records. However, since weather stations are not homogeneously distributed in the country, they do not provide spatially-and temporally consistent records that make multi-decadal.

5.3. Digital Technologies and climate adaptation initiatives in Zimbabwe

Smallholder farmers are active participants in the digital technology space with those negatively affected by climate change adopting technologies which help them cope with the situation. Farmers have shown they can adapt some of the technologies well (such as use of mobile phones, social media applications, radio and televisions) and become as lead farmers[4]. Mostly these are well resourced farmers who can afford to purchase the gadgets and in some cases data for connectivity. These lead farmers are instrumental in allowing farmers that do not trust the technologies evidence on the benefits of adopting the tools. During the rolling out of the Pfumvudza concept (climate-smart agriculture technique), the government used the demonstration plots where farmers could come and learn so that they can uptake the method at their own farms and this has been very successful although it is labour intensive. The government through the DR&SS in partnership with various partners such as academia, NGOs have been involved in research focusing on finding solutions to the climate change challenges faced by farmers. Farmers are having access to weather information that aids the process of choosing crops and planting dates such that the crop does not suffer moisture stress mid-season. A number of programmes and projects by the Government, private sector and development partners are implementing activities to promote the adoption and use of digital tools in climate change adaptation.

The Zimbabwe Resilience Building Fund (ZRBF) programme is promoting the use of digital weather stations in districts where it is implemented including Kariba which is in the Zambezi basin. It is also promoting e-extension through a mobile App, e-marketing App and financial App through Kurima Mari[5]. The ZRBF programme is also promoted use of digital technologies in boreholes to monitor the abstraction of groundwater to avoid over abstraction. The Food and Agriculture Organization (FAO) under the Livelihoods and Food Security Programme (LFSP) piloted and funded the Kurima Mari App which is an application used for group savings and lending by a group of smallholder farmers. The App requires investment in connectivity and data by members. Also, the policy environment should encourage investment in expanding network coverage to other areas to enable wider use. The USAID under the AMALIMA[6] project promoted a number of mobile Applications for Early Warning System, crop focusing and vegetation mapping among others. The major challenges in adopting and expanding mobile applications were infrastructures, technical skills, connectivity challenges and availability of requisite gadgets.

A private sector company, Financial Securities Exchange (FINSEC) is operating both the Warehouse Receipt System and Commodity Exchange platforms. These platforms are run/operated through a mobile

[4] A lead farmer is a farmer chosen by other farmers to represent them in agricultural development and train them to use new technologies. He/she is expected to motivates other farmers to try new technologies and usually lead by example by practising what they are taught on their own fields..They are selected based on their technical expertise, their role in the community and their level of literacy. https://www.n2africa.org/sites/default/files/N2Africa%20Poster%20Isaac%20.pdf

[5] Kurima Mari; https://play.google.com/store/apps/details?id=zw.co.kurimamari&hl=en&gl=US

[6] AMALIMA draws its name from the Ndebele word for the social contract by which family comes together to help each other engage in productive activities such as land cultivation, livestock tending and asset building; https://www.cnfa.org/program/amalima/

application which is available to farmers, input suppliers, traders and consumers. Econet, a mobile cell phone company is promoting 'Eco Farmer' which is a mobile platform where extension messages are available for farmer's use. The platform is interactive, and farmers can ask questions and get responses. The major challenges with this are connectivity and data as it requires the internet to operate. Most farmers face data and connectivity challenges to utilize these platforms.

The Dairy Farmers Association of Zimbabwe has developed a mobile App to assist dairy farmers to access inputs, finance, extension and marketing services. Some farmers are skeptical about the use of technology as they fear losing industry secrets which give them a competitive edge. Some farmers cannot use the Application because they do not have smartphones.

According to the Zimbabwe National Policy for Information and Communication (2015), the ICT sector has been experiencing a number of challenges. Some of the listed challenges are;

- Inadequate communications infrastructure- Broadband coverage is mainly concentrated in affluent urban areas that is widening the urban-rural digital divide against the principle of equitable access.
- Inadequate Commercial Electricity- The national power grid does not cover the whole country and supply is erratic. A significant population is dependent on expensive alternative power sources. The electricity shortage has had adverse effects on the development and use of ICT.
- ICT skills: - The shortage of ICT skilled manpower is hampering the roll-out of ICT programs. This shortage has a knockon digital literacy which drives uptake and usage of ICT services.
- Low digital literacy level: - The education curriculum does not include ICT; therefore, the level of digital literacy at the grassroots level is very low to stimulate service uptake and usage, especially in rural areas.
- The high cost of data/ bandwidth has made data beyond the reach of many Zimbabweans.

Digital technology for climate change adoption requires that fundamental infrastructure and a conducive policy environment to be in place to increase uptake and use. Key infrastructure such as base stations, reliable energy, sources, digital weather forecast equipment, human capacity at the weather forecast station, investment in farmers' education, collaboration between the government and the private sectors (credit providers, banks, insurance providers, network providers) and a conducive policy environment are needed to support adaptation of digital technologies in Zimbabwe. The table below summarizes key roles played by stakeholders in promoting digital technologies.

Table 8: Promotion of digital technology adaptation by different stakeholders

Institution	Key Role in promoting Digital Technologies
Government	• Create an enabling environment for investments and Public-Private – Partneships (PPP) • Invest in public infrastructure • Come up with incentives for investment in the digital adaptation technologies • Enhence digital skills through mainstreaming ICT skills in the academic carriculum
Private sector	• Invest in the digital technologies sector • Mobilize resources
Development partners	• Stakeholder awareness • Pilot new technologies

	• Provide grant funds to public and private entities involved in digital technologies • Development of knowledge hubs and information sharing platforms

Source: Stakeholder Consultation Workshop, Zimbabwe (2022)

5.4. List of technologies that can be considered for mainstreaming into adaptation

Stakeholders came up with a list of digital technologies for use in climate change adaptation during the stakeholder consultation workshop held on the 8th of March 2022 (See Annex 3).. Zimbabwe has to expand digitalization as shown by the importance in the implementation and achievement of vision 2030. The following technologies have been identified to have the highest potential and impact in terms of digital adaptation to climate change.

a. Early warning system - using integrated communication systems to help communities prepare for hazardous climate-related events. Through the early warning, it allows detailed mapping and reporting current and projected food insecurity, alerts on emerging or likely crises, Special reports on factors that contribute to or mitigate food insecurity, including weather and climate, markets and trade, agricultural production, conflict, livelihoods, nutrition, and humanitarian assistance. However, the cost of the tools limits their adoption.
b. Financial payment platform-an innovative mobile payment solution that enables customers to complete financial transactions directly from their mobile phones.
c. Radio (community radios) FM radio promotes awareness of climate impacts and mitigation in some of the globe's remotest and most undeveloped regions. The radio has emerged as a tried, tested and dependable powerful medium of communication for multiple audiences, and stakeholders including the broad network and a wide cross-section of farmers. The popularity of the radio means that it is a highly effective tool for spreading information and agricultural advisory services, especially in a changing climate by connecting farmers to vital information banks designed to improve their livelihoods and resilience. In this regard, radio is there to close information gaps created by other forms of mass media and avoid the dearth of information on climate change. In terms of climate change awareness and reaching out to marginal and remote communities, radio has proved to be the most powerful and trusted medium of choice. The unique feature of radio is that it provides services designed to help farmers overcome illiteracy barriers through broadcasting in their own languages.
d. Internet - serve as a critical enabling tool to mitigate climate change and adapt to it, e.g. through climate monitoring and data collection, which can assist agriculture and other sectors, in predicting natural disasters and ensuring a rapid response when disasters strike (Coalition et al., 2009).
e. Mobile phones- use of mobile phones is very high in the country, therefore using them to disseminate information ensures wide coverage.
f. Weather indexed insurance-financial adaptation option that pays out benefits based on a predetermined level of a weather variable e.g., rainfall level, temperature, floods or droughts.
g. E-extension, e-government, e-commerce, various ministry websites- Communicate, create, store, disseminate and manage agricultural information. The material that is used for training can be shared on various platforms such as radio, TV, SMS, video and social media platforms, therefore increasing coverage. Farmers can access the information at a time of their choosing unlike having to attend farmers' training. The material can be served, and one can refer back whenever they wanted.
h. GIS remote sensing is a system designed to capture, store, manage, analyse, manipulate, and present geographic or spatial data which information in generating information to make informed decisions.
i. Social media-allows the dissemination of information in a short space of time.
j. Buying and Selling Online/E-Commerce/E-Markets;allows transcations to be initianted and finalised remotely through the internet without the need for physical interaction.

k. Video Streaming & Digital Music; Streaming is the continuous transmission of audio or video files from a server to a client. It allows anyone with digital device and internet access to access stored or real-time information without downloading media files. This technology allows smallholder farmers to access information or attend online learning platforms without the need to be physical;y present or downloading a lot of media data which takes up a lot of storage space.
l. E-Books; Is a book presented in a format that allows farmers /anyone to read it on an electronic device like a computer or handheld device hence farmers can easily access critical information related to farm production;
m. Computers, Printers and Self-Scan Machines; an electronic device for storing and processing data, typically in binary form, according to instructions given to it in a variable program and can carry out task based on inputted commands.
n. Automated Teller Machines (ATMs); is s a specialized computer that allows bank account holders to conveniently access their bank accounts, check account balances, withdraw or deposit money and print statement of accounts.These can be deployed further away from banks ;
o. Digital Cameras; captures photographs in digital memory and allows these to be shared through e;lectornic means as well as being stored without utilising a lot of space.
p. Smart watches; is a protable device that is worn on the wrist and these interfaced with mobile devices and computers and allow anyone to access services or apps on their devices.
q. E-Mobility; represents the concept of using electric powertrain technologies, in-vehicle information, and communication technologies and connected infrastructures to enable the electric propulsion of vehicles and fleets.Thus this maybe important for smallholder farmers in remote areas were there is no access to fossil based fuel to make use of electric powered tractors or vehilces.

However the stakeholders ranked the following as priority technologies for climate change adaptation based on their own understanding; Early warming systems, Community radios & E-extension, and also priortised the following gadget and equpment; GIS & GPS and Smartphones & Computers.All the other technologies and eqipment are important but were not prioritised.The prioritisation was based on cutrrent use, importance and accessibility.

5.5. Digital technologies for Climate Change Adaptation

Digital technologies are very instrumental in enabling better adaptation to climate change. Adaptation is the process through which societies increase their ability to cope with an uncertain future involves taking appropriate action and making adjustments and changes to reduce the negative impacts of climate change (UNFCCC, 2007). Smallholder adaptation to climate change risks and hazards requires a transformation of the production system to achieve food, nutrition, and income security by vulnerable groups. However, suitability of digital technologies varies greatly depending on the production system, climate hazards exposure and the farmers' access to resources . Adoption of various ICT tools in agriculture will improve climate resilience for smallholder farmers, boost productivity, improve access to financing and markets for all value chain actors, and address social inclusion gaps for the youth, women, and marginalized groups. The COVID -19 pandemic highlighted the need for the provision of an enabling environment to support mainstreaming of digital solutions in the transformation of agricultural production systems. Digitalization provides a solid foundation for timely access to information and services, based on a solid data infrastructure needed for response, recovery and building resilience to climate change and other disasters, especially in vulnerable communities such as the Zambezi basin.

The falling cost of digital technologies presents an opportunity for smallholder farmers in the Zambezi basin to access technologies that can improve productivity, incomes, and resilience at the household level and at the food systems level (FAO and ITU, 2022). This promotes the building of more adaptive capacity and agile value chains using data, leveraging the power of satellite observations and geo-data to address

pest and disease threats; the development of novel solutions for supporting farmers' social protection; and the enhancement of traceability systems applied to food products from farm to fork (FAO and ITU, 2022). Digitalization in agriculture is not without its challenges, since less than 25 percent of individuals in sub-Saharan Africa access and use the internet (World Bank, 2019).

5.6. Adaptation practices

Small-scale farmers are the backbone and cornerstone of agricultural and food supply chains in Zimbabwe (FAO, 2015). Agricultural practices in smallholder production systems are sometimes not economically viable and struggle to be sustainable. Yield is generally low, and this is being worsened by climate-related hazards such as erratic rainfall patterns, prolonged dry spells and high temperatures resulting in low productivity in both crops and livestock hence food insecurity (USAID: 2019a). The middle parts of Zambezi basin fall within the high climatic risk zone as experienced by the high occurrence of risks such as erratic rainfall and recurrent droughts (World Bank, 2020). Lack of information about critical inputs and inadequate knowledge about modern and efficient agricultural practices are some of the factors that contribute to low yields, hence digitalization reduces information asymmetries, transaction costs and improves service delivery. Digitalization allows farmers to generate new income streams and conservation of resources (World Bank, 2017). Small-scale farmers continue to struggle to receive quality advisory services (including weather information for timely decisions on when, how, and what to plant, etc.) to optimize crop yield and epidemics, or information that could enable farmers to transport crops more effectively to markets and sell them at better prices. Small-scale farmers can use ICT to match cropping practices to climatic trends, use inputs and resources sustainably, and cope with productivity threats. Increasing the efficiency, productivity and sustainability of small-scale farms is an area where ICT can make a significant contribution, especially with the use of ICT tools such as mobile, and Internet technologies. ICT has the potential of transforming small-scale agriculture, however; it all depends on whether the tools are affordable, scalable, self-sustaining, sensible, participatory, and appropriate. Through the adoption of ICT, youth participation in agri-food system can be improved, and small-scale farmers will have improved access to information and markets. Some other benefits of digital technologies include:

a. easy access to agricultural information; new farming techniques and new food storage and processing technologies; finance and climate adaption technologies;
b. Provision of information on weather, soils, crop, and animal disease outbreaks;
c. Effective communication with other farmers; public and private extension agencies, quick access to information on market prices of crops and livestock and farm inputs such as fertilizer, agro-chemicals; and
d. Availability of information on sources of credit, subsidies, weather index-based insurance and loans for farming and investing in climate adaptation technologies (Agwu and Mbah, 2012).

Digital innovations have great potential to transform smallholder agriculture in the Zambezi basin with modern large-scale agriculture increasingly dependent on precision agriculture tools such as a global positioning system (GPS), Artificial intelligence, Block chain, satellite, and drone monitoring, and increasingly detailed and instantly available weather and climate information. Regardless of these same tools, being useful and necessary in smallholder production, costs are a major barrier to the adoption of these digital technologies. Stakeholders raised this issue many times during the consultation workshop in Harare. Technology cost is deterring adoption in small-scale production. Some of the digital tools that are key to the transformation of agriculture include the following:

i. **Artificial Intelligence:** Artificial Intelligence (AI) is critical in large-scale farming but can also be used in smallholder farming areas. This tool can be applied in the following areas:
    a. smart agriculture;
    b. robotics; agricultural optimisation management;

c. automation of processesagriculture systems and activities;
d. agricultural knowledge-based systems; and
e. Decision support systems.

Decision support systems. Digital technologies can be used to generate information that can guide deceision making such as prevailing weather conditions including temperature, rainfall, wind speed, wind direction, and solar radiation; control pests; monitor soil and growing conditions; and improve efficiency along the food supply chain. In Zimbabwe, AI technology is not widely deployed in smallholder farming areas. Some commercial farmers and universities are piloting the use of the technology.

ii. **Agriculture Drones (unmanned aerial vehicles)**: Drones have a huge potential in agriculture transformation by supporting evidence-based planning and spatial data collection. Drones can scan a vast area of the field and work with different sensors to gather a wide range of information at ease. Drones can also perform crop-spraying tasks more efficiently, with greater accuracy, and less waste. Thus, for the most part, drones make sense because they can replace labour-intensive and potentially harmful use of backpack sprayers.

iii. **Global Positioning System (GPS)**: One main area where GPS has found importance is in the field of precision farming. Linking to a system of satellites, a farmer uses a receiver to pinpoint his or her position within inches. GPS can be used for Soil sampling; Weed location; Accurate planting; Harvesting; Identification of irrigated crops; Autopilot operations; and Crop inventory.

iv. **Block chain**: During recent years, Block chain has attracted significantly increasing attention in the agricultural sector in line with food safety through traceability of provenance, information system, agro-trade, finance, and crop certification. As a trusted way of storing data, Block chain facilitates the use of data-driven technologies to make farming smarter. In addition, jointly used with smart contracts, it allows timely payments between stakeholders (farmers, buyers, and Agro-dealers) that can be triggered by data changes appearing in the Block chain. This technology is not commonly used in Zimbabwe.

v. **Remote sensing**-Pest and disease surveillance monitoring at regional, national, or even farm and field levels to record the prevalence and severity of pests and plant diseases monitoring of crop growth/damages, yield. Monitoring of flood inundation etc.; crop growth/damages, yield. Monitoring of flood inundation typically goes beyond simple monitoring to include early warning and advice on pest and disease management. The country is yet to fully benefit from this technology as a result of limited satellite access.

vi. **Weather and climate infrastructure-**Physical (e.g., weather base stations) and digital infrastructure play a role in collecting and recording and delivering real time data on climatic conditions and weather parameters at various levels of geographic granularity, from regional weather patterns down to the agro-climatic conditions (e.g., level of precipitation and temperature) for a farm or specific farm field. The meteorological service department has numerous weather stations and weather observation points to increase the accuracy of weather reporting.

Weather index-based insurance-Agricultural insurance uses a weather index such as rainfall to determine pay-outs, thus allowing the system to manage weather and climate risk. The use of weather index-based insurance is on the rise through applications such as Eco farmer which is offered by one of the biggest telecommunication companies in the country.

A number of digital applications are currently available for use in water management, agriculture, irrigation, flood, and drought warning, finance are summarised in Table 9.

Table 9: Existing digital apps relating to water management, agriculture, irrigation, flood and drought warning, finance

Digital adaptation	Tool	Purpose
E-government services	-Websites and digitalization of all systems and processes Online agriculture import and export permit application on Ministry of Lands, Agriculture, Fisheries , Water and Rural Development website, Public Finance Management System (PFMS), Zim Agric Extension app[7]	use of ICTs in facilitating online registration, online service delivery, e-public services, e-revenue and one-stop service, or integration of all Government services to citizens and businesses.
E-agriculture services	E-extension- Farming apps e.g., kurima Mari, Agri Share, SMS, Farmer radio programs	Involve the conceptualization, design, development, evaluation and application of innovative ways of using ICTs in the rural domain, with a primary focus on food and agriculture.
E-insurance	Eco-farmer app	Protect against losses in the event of natural hazards e.g. drought, floods, cyclones
Smart agriculture	Precision agriculture Adoption of technology at the production level e.g., drones, moisture sensors, self-driving vehicles and automated machines e.g. CASSAVA Smartech (VAYA)	Use of technology to improve the efficiency of production and improve quality. Precise application of inputs incorrect quantities and time
E-commerce in agriculture	Online shops e.g. Kurima Mari, okonline.co.zw , desertcart.co.zw	Allows buying and selling of goods via the internet
Risk transfer	Risk transfer instruments such as weather index insurance and price hedging e.g Zimbabwe Mercantile Exchange (ZMX)	Minimise loss by farmers in the event of a risk.

Source: Authors illustration

Digital technology adaptation to climate change in agriculture is being spearheaded by value chain players including Government, private sector, development partners and civil society. Digital technology development focus on different points on the value chain i.e., inputs, production, distribution, retail, and consumption.

Data-driven digital services are important for farmers' decision-making in the following ways:

i. **Planning** – Data-driven digital services can help the farmer to plan what to produce, when to produce, where to produce, whom to produce, and what operations to do when and where on the

[7] Zim Agric Extension app; https://play.google.com/store/apps/details?id=app.agritex.training&hl=en&gl=US

farm. Providing real-time weather data, market data, crop and animal growth models, and soil would greatly help for better planning and efficient farm operations.

ii. **Monitoring and assessment** – To monitor the growth of crops and the status of the natural agricultural resources using data from sensors.
iii. Event management and intervention – Soil data from sensors can help farmers to decide which soil improvement action to take and when.
iv. **Autonomous actions** – Switching on water pumps to irrigate fields when soil humidity falls below a target amount and auto feeding animals at different times of the day.
v. **Optimization** – Market data, consumption statistics, land and water use data can help a farmer decide what the economic, environmental or social effect on the investment or action will be.
vi. Other ways include forecasting for example expected crop and animal output/ yield
vii. **Tracking and tracing** – where is the product both crops and livestock, item, resource or material?
viii. **Negotiation and market access** – Where are the customers? What do they want? Who else is selling the same product? Which service providers can I best work with? what will help the farmer to negotiate better prices, price discounts etc.The Zimbabwe Commodity Exchange is one example where farmers use technology to interact with the market (buyers and sellers).

Digital technologies have been very instrumental in supporting farmer decision making based on information received. Some of the digital platforms that have been used are radio programs used to convey impending disasters such as storms. Farmers have also been getting weather and market information through digital platforms. This has allowed farmers to have access to expert advice virtually.

The use of digital technologies in Early Warning Systems has allowed smallholder farmers and other stakeholders to rapidly be able to respond and better prepare for a disaster. Messages are transmitted through a variety of digital platforms such as the radio, television and different social media platforms. Farmers have also made effort to make use of the information they receive to improve preparedness as observed through preparedness to disaster, adoption of conservation agriculture technologies such as Pfumvudza programme, especially in drought-prone regions including the Zambezi basin.

5.6.1 Enhancing adaptation through digital innovation

Digital adaptation is very important as it improves the quality of information and its dissemination such that appropriate action is taken in response. Climate models predict changing rainfall patterns for most of Zimbabwe, with overall decreasing rainfall, farmers have to decide which crop and variety to grow and to ensure the crop has a better chance of surviving and producing optimum yield. Through raised awareness that inspires adoption of the appropriate digital adaptation action, a more resilient production systems are developed increasing food security and resilience of the community (*See Annex One(1) on Kurima Mari application*). As farmers witnessed climate change impacts and received confirmation through weather forecasts it became clear for farmers on the need to climate proof for their production systems through the adoption of climate smart practices. These practices vary with the production systems and there are practices that can be adopted by resource poor communities and those that require bigger financial investments. Some of the digital adaption tools include:

- better-informed decision-making by farmers on agronomy and planting dates, e.g., by providing agronomic advice, weather and climate forecasts, or drought warnings,
- better-informed decision-making by extension services and policymakers, e.g., by providing climate forecasts and early disaster warnings,
- economic risk transfers, e.g., through index-based insurance schemes, and
- Access to improved financial information and services, e.g., market information and credit.

These services aim at enhancing key activities related to agricultural productivity, post-harvest handling, market access, finance, and supply chain management so as to increase household incomes for smallholder farmers, expand the economic inclusion of vulnerable persons, such as youths and women, and improve food security and nutrition so that smallholder farmers can purchase and consume nutritious foods and build their climate resilience. Table 10 shows adaptive capacity of access to agricultural information and the adoption of improved agricultural practices by provinces. The Mashonaland West province is ranked first in its adaptive capacity while Matabeleland north and south are ranked 7 and 8 respectively. All provinces have very high literacy levels with the lowest at 96 percent while Matebeleland North and Midlands have 100percent literacy levels. Masvingo has the highest access to agricultural information with a score of 81percent while Matebeleland North is lowest with 32 percent. Mashonaland Central leads in terms of adopting improved agricultural practices at 72 percent and has the adaptive capacity score of 81percent (Table 10).

Table 10: Ranked adaptive capacity (AC) Indicators scores for Provinces of Zimbabwe

	Adoption of improved agricultural practices	Access to agricultural information	Education	Adaptive capacity score	Adaptive capacity rank
Manicaland	0.41	1	0.99	0.76	5
Mashonaland Central	0.72	0.6	0.96	0.81	3
Mashonaland east	0.54	0.76	0.99	0.76	4
Mashonaland west	1	0.73	0.98	1	1
Masvingo	0.5	0.81	0.98	0.75	6
Matebeleland North	0.25	0.32	0.96	0.48	7
Matebeleland south	0.09	0.36	1	0.42	8
Midlands	0.66	0.77	1	0.83	2

Source: Hunter *et al.* (2020)

Digital advisory services can help facilitate responding to adaptation challenges faced by farmers in Zimbabwe by informing flexible and data-driven responses to climate variability, other related hazards, and other relevant information such as pest and disease outbreaks and more. This is very important as it improves the chance of improving yields and achievement of food security. Through increased yield farmers are assured of sufficient food and nutrition. Surplus yield can be sold, and the money can be used for savings or investment in more digital climate adaptation tools.

5.6.2 Role of climate finance as an opportunity

Enhancing climate finance involves adjusting policies and actions because of observed or expected changes in climate. The government plays a key role in creating an enabling environment that promotes the adaptive capacity of vulnerable communities and empowers them to adapt and respond to the climate hazards and risks; by attracting investment in climate change adaption for example investments in digital infrastructure for climate change adaptation and mitigation.The base infrastructure is public infrastructure and that requires public financing e.g radio transmitters whilst private sector financiang is required in the subsequent nodes of the chain e.g. cellphone base stations and fibre optic cables. If resources are available more could be done in terms of research, deployment of the tools, awareness creation and use of digital technologies in climate change adaptation. In general there is lack of appropriate finance to acquire and deploy most of the technologies as the initial investment costs are considered high such as purchase of GPS equipment, smartphones automated weather stations.

Zimbabwe is a beneficiary of Green Climate Funding whose objective is equipping communities to cope with climate change and budiling resilience for household food and nutrition security.Through this project and other initiatives the country is also being assisted to develop the National Adaptation plans (NAPs) which have strategies and tools to address local climate change-induced problems.Some of the strategies include use and support digital technologies in addressing climate change issues.

The Zimbabwe Resilience Building Fund (ZRBF), a multi donor fund is also implementing a resilience building program which covers some districts like Binga, Kariba and Mbire districts which fall under the Zambezi River Basin. Interventions include capacity building in Disaster Risk Reduction (DRR) strategies and also provision of infrastructure such as automated weather stations. These are some of the innovative ways of funding climate change adapattaion including use of digital technologies.

5.6.3 Required investments to maximize potential

The Zambezi basin has poor infrastructure therefore there is a need for infrastructure upgrades that include the development of road networks and rural electrification programs. In general, the country has good ICT, however, there is a need for improvement in the Zambezi basin as there are grey areas where there is no network coverage. This disadvantages the communities as it limits their access to information. There is a need for ICT Infrastructure upgrades to ensure efficient communication in real time. There is a need for rural electrification or subsidies that encourage each household to invest in solar energy considering the high levels of power cuts in the country. There has been an increase in mobile and internet penetration and together with the availability of affordable smartphones and computers, this has scaled up the use of these tools as well as increased climate change adaptation awareness.

Although there maybe challenges with the language barrier which can be addressed through the translation option on smartphones or use of community radio systems that broadcast using the local language in that area. Intercative Voice Response (IVR) tools can also be used to address the language barrier through having multiple language options for farmers to choose from. Digital tools have many functions that ensure everyone can access and understand the information. There is a need for capacitation such that people have the skills and know how to operate the tools. The availability of affordable cheap phones will provide women an opportunity to own phones and get equal access to information and enhance their preparedness. By adoption of digital tools and scaling up it is not only useful for information delivery but also facilitates data collection to be come fast, cheap and more reliable. To encourage digital technology adoption there is a need for all stakeholders to be involved, the government can promote locally produced ICT equipment, and this will further reduce cost while generating employment.

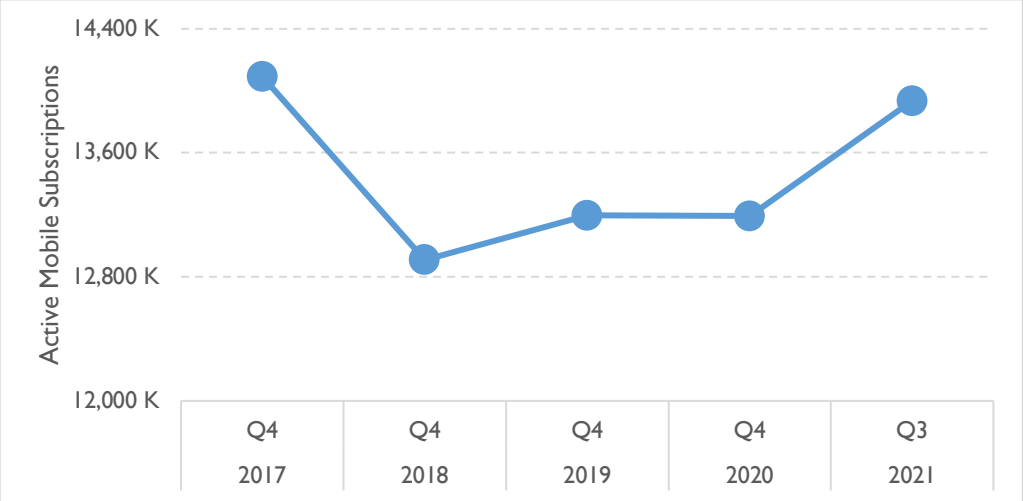
The minimum investments required to enhence uptake of the identified digital technologies include;

i. Capacity building of farmers, extension agents and support services such as Meterological Services Department (MSD) and Civil Protection Unit (CPU) to improve coordination and knwoldege sharing on disaster preparedeness abd implementation of other management practices;
ii. Invest in content creation on climate change adapatation for dissemination to farmers, extension officers and service providers.In addition invest in translating climate change adapatation information into local languages;
iii. Invest in promotion of climate smart innovation technologies including awareness campaigns on the use of digital technologies for climate change adaptation; and
iv. Invest and facilitate access to some digital gadgets such as smartphones and tablets by key agents such as Extension Services, Meterologiacla Services Departmenst and Civil Protection Unit (CPU).This can be supported through a policy to exempt gadgets from paying taxes and duties hence making them affordable to smallholder farmers hence making them affordable to smallholder farmers.

6. Zimbabwe Digital Adaptation Readiness

Zimbabwe has a well-developed telecommunication infrastructure with wide coverage in most areas, however, grey areas exist in some areas. Overall, theEnabling the Business of Agriculture Score, for Zimbabwe is 48.36 out of 100. This implies that there are still many barriers to doing business in agriculture including policy, regulatory, infrastructural and access to finance among others. There are four major telecommunication companies which are Telone, Econet, Net one and Telecel and several small service providers. The price of communication gadgets and SIM cards are comparable to regional prices, therefore, providing an opportunity to scale the adoption of digital tools and enhance climate change adaptation. On average, the country has about 13 million active mobile subscribers. The decline in active mobile subscriptions in 2018 was attributed to a clean-up exercise by Net one (mobile network operator) on its subscriber database and loss of subscribers by another mobile network operator Telecel. Figure 8 below shows the trend in active mobile subscriptions between 2017 and 2021.

Figure 8: Active mobile subscriptions (2017 – 2021)



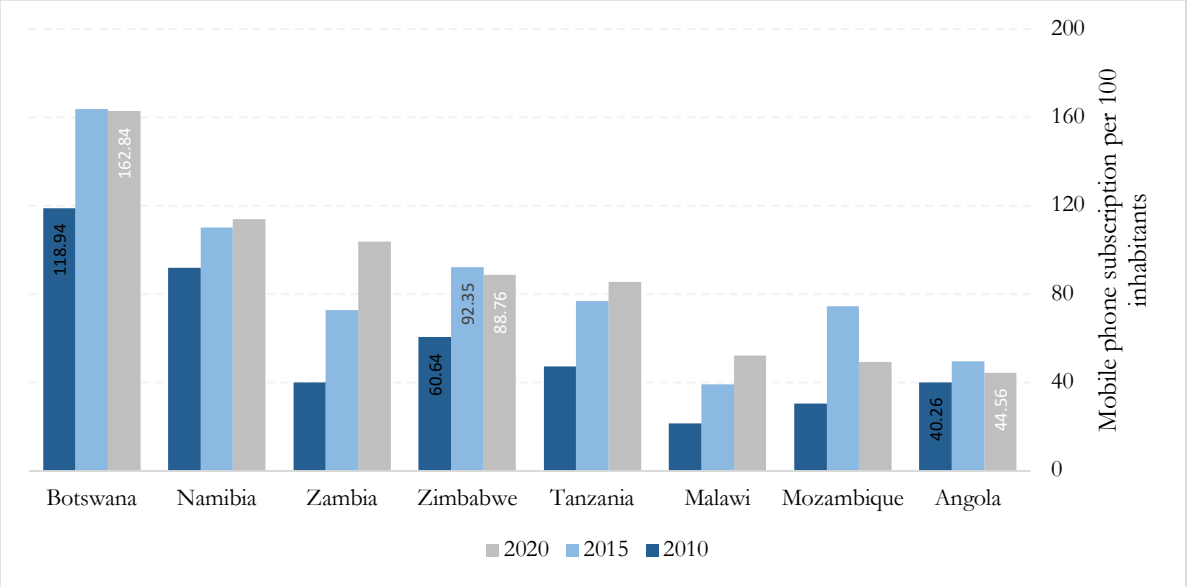
Source: Postal & Telecommunications Sector Performance Various Reports (POTRAZ)

Active mobile subscriptions have been experiencing seasonal fluctuations since the onset of the COVID Pandemic due to demand and consumer behaviour related to restrictions of the COVID-19 pandemic, active mobile subscription declined between Q4 2019 and Q4 2020 see Figure above (POTRAZ;2020). The mobile penetration rate declined by 2.7percent to reach 87.8percent in 2021, from 90.5percent recorded in 2020. Despite the drop, coverage is still very high according to POTRAZ (2021). Quarterly mobile voice

traffic has been on the rise rising from 1.33 billion minutes in Q1 2020 to 2.11 billion in Q3 2021 (POTRAZ; 2021).

A comparative analysis of mobile phone subscriptions between 2010 and 2020 in the riparian countries of the Zambezi shows that Botswana had the highest mobile penetration rate of 162.84 mobile phones per 100 inhabitants in 2020 compared to 118.94 in 2010 whilst Angola had the least penetration rate of 44.56 mobile phones per 100 in 2020 from 49.79 mobile phones in 2015. In Zimbabwe mobile penetration rate stood 88.76 mobile phones per 100 people in 2020 compared to 92.34 in 2015, hence there have been a reversal in the gains made in 2015 (Figure 9).

Figure 9: Mobile phone subscription per 100 inhabitants in 8 riparian countries of the Zambezi in 2010-2020



Source: ITU World telecommunication/ ICT indicators database

With regards to internet penetration, Zimbabwe fares favourably against other regional countries, but the penetration rate remains very low at 11 percent. This low penetration presents challenges associated with adopting digital technologies that use the internet to link up with farmers (POTRAZ, 2021). Based on the climate projection in Zimbabwe, the impacts of climate change are expected to increase in intensity and frequency, therefore, there is a need for transformation towards climate-smart and resilient food systems through the adoption of digital solutions to climate change adaptation. The adaptation processes are a result of their ability to implement adaptive decisions, thus transforming that capacity into action (functioning) (Nelson et al., 2007). Capabilities can, therefore, be understood as the capacity to implement adaptive decisions. In turn, the adaptation processes can lead to system transformations when new livelihood strategies are adopted (e.g., when climate-related disturbances force systems to depend on new, diversified livelihood options), as well as system adjustments, when systems are improved to reduce vulnerability and strengthen future adaptive capacity. However, there are limits and barriers to adaptation in the agriculture sector. These limits can be natural, technological, economic, social or institutional. Natural limits range from ecosystem thresholds to geographical and geological limitations .Table 11 below summaries some of the barriers to adaptation of digital technologies .

Table 11:: Barriers to adaptation of digital technologies (technological, infrastructure and capacity)

Technological	Infrastructure	Skills /Capacity
Cost of technology	lack of business entities developing the digital economy	Inadequate investment capital and financing to scale adoption

Affordability of smart devices and other ICT products		of climate change adaptation digital tools;
Limited local ICT innovation, Research and Development (R&D) and entrepreneurship;	Interoperability challenges	Lack of appropriate policies to support ICT sector growth and climate adaptation;
Unavailability of digital technologies	Inadequate communications infrastructure (e.g., water, internet, electricity, road and Rail networks) e.g., presence of still grey areas without network/radio coverage	Level of Education, ICT Knowledge and Skill of individuals. Low digital literacy among this critical mass. Additionally, on average, women have less access to the internet than men;
Limited access to technological infrastructure gadgets	Network connectivity challenges because the coverage is still growing	Credit and insurance constraints
	Restricted access to technologies such as satellites	lack of confidence in developing and adopting local technologies
		Weak agriculture insurance

Source: Stakeholder Consultation Workshop, Zimbabwe (2022)

Table 12 summarises some key statistics on the readiness of some digital technologies for climate change adaptation. The population of Zimbabwe covered by mobile cellular networks stood at 95.3percent in 2020. Households with internet access at home was at 50.1percent whilst those who own computers at home is 14percent these figures are still low. Only 3.9percent of individuals in the country have basic skills which becomes a barrier to the adoption and use of digital technologies. The proportion of households owning computers and mobile phones has been rising and in addition, the proportion of active mobile cellular subscriptions and mobile broadband subscriptions per 100 inhabitants also rising (Table 12).

Table 12: ICT indicators

Indicator	2007	2019	2011	2013	2015	2017	2019	2020
Population covered by a mobile -cellular network (%)			72.0	84.0	89.0	90.0	93.0	93.0
Mobile -cellular subscriptions per 100 inhabitants	10.0	31.9	71.3	102.1	92.3	99.0	90.1	88.8
Active mobile -broadband subscriptions per 100 inhabitants		0.2	14.7	40.1	42.5	47.9	51.7	
Fixed telephone subscribers per 100 inhabitants			2.8	2.3	2.4	1.9	1.8	1.7
Fixed broadband subscribers per 100 inhabitants			0.3	0.8	1.2	1.3	1.4	1.4
Individuals owning a mobile phone (%)								89.6
Male internet users as a percentage of the total male population (%)			28.9		37.2			28.9
Female internet users as a percentage of the total female population (%)								30.0
Households with Internet access at home (%)								50.1
Household with a computer at home (%)			14.0		14.0	14.0	14.0	14.2
Individuals with basic ICT skills (%)							15.0	3.9
Affordability, out of 100 ([21)]								
Price per GB (US$) ([22)]				45.0	80.0	35.0		11.2
Mobile cellular basket as a percentage of GNI per capita (%)				20.1	12.9	13.4		
Mobile broadband basket as a percentage of GNI per capita (%)						23.5		

Source: World Bank Development Indicators; ITU Statistics[8] and Zimstat/POTRAZ (2020)

The E-Government Development index reflect how a country is using information technologies to promote access and inclusion of its people, Zimbabwe scored 0.5019 in 2020 (on a scale of 0-10, 1 being the best) and was ranked 126 of 193 in 2020 from 133 out of 193 in 2012. E-participation assesses the quality, relevance and usefulness of Government websites in providing online information and participation tools and services to the citizens, thus as of 2020 the country has been indicating that there has been improvement in the citizens access to information and some public services through online platforms. With regards to network readiness Zimbabwe has been progressing at slower pace compared to other countries in terms of its readiness to exploit opportunities offered by ICTs as indicated in Table 13.

8. World Bank Development Indicators; https://data.worldbank.org/indicator/IT.CEL.SETS ; International Telecommunications Union (ITU) Statistics- https://www.itu.int/en/ITU-D/Statistics/Dashboards/Pages/Digital-Development.aspx ;

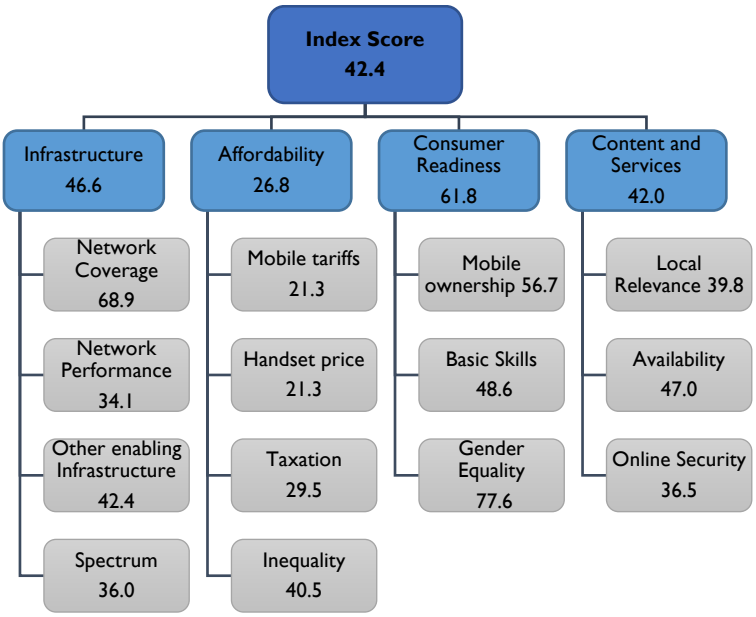
Table 13: ICT Readiness Indicators

Indicator	2012	2013	2014	2015	2016	2017	2018	2019	2020
E-Government Development index (23)	0.3583		0.3585		0.3472		0.3692		0.5019
***Rank out of 193 countries**	133		126		134		146		126
E-Participation Index (23)	0.0263		0.4510		0.2881		0.2753		0.4524
***Rank out of 193 countries**	134		75		127		151		122
Network Readiness Index (240								22.09	25.78
***Rank out of 134 countries**								119	126

Source: E-Government Development index, 2020, Department of Economic and Social Affairs, Public Institutions, United Nations;

The Mobile Connectivity Index measures the performance of countries, against the four key enablers of mobile internet connectivity. It has been built to support the efforts of the mobile industry and the wider international community to deliver on the ambition of universal internet access. Zimbabwe is still below the 50% mark in terms of the 2021 GSMA Mobile Connectivity Index.The country scored better on consumer readiness where it has a score of 61.8 whilst the least performing enabler is affordability were the country has a score of 26.8 and this has a bearing on adoption of technology that relies on GSMA technology (Figure 10).

Figure 10: Zimbabwe Mobile Connectivity Index



Source: 2021 GSMA Mobile Connectivity Index[9]

[9] https://www.mobileconnectivityindex.com/#year=2021&zoneIsocode=ZWE&analysisView=ZWE

Table 14 summarises Zimbabwe's readiness to adopt digital technologies. Mobile money (million) active accounts and cellular subscriptions have been increasing at a rate of more than 35 percent per year. Also, individuals using internet facilities has been increasing but it is still very low at 25.1percent as of 2019, whilst the number of fixed telephone subscriptions has been declining as preference has shifted to mobile communication technologies.

Table 14: Digital uptake

Digital technology/service	2011	2013	2015	2017	2019	2021
Mobile cellular subscriptions (per 100 people)	71	102	92	99	90	
Mobile money (million) active accounts		1.87	4.68	4.61	6.54	
Weather index insurance		Econet (2013/14): 1,100 farmers	Zimnat (2014/15): 3700 farmers/ Econet (2014/15): 435 farmers	Ecofarmer -700,000		
Individuals using internet -% of population	8.4	15.5	22.7	24.4	25.1	
Secure internet servers	12	64	162	435	991	
Fixed broadband subscriptions (per 100 people)	0.26	0.78	1.19	1.32	1.37	
Social media (million)						1.3
Smart phones			15%			
Fixed telephone subscriptions ('000)	356	304.16	333.70	264.15	265.73	

Source: Reserve Bank of Zimbabwe annual reports, Carlos (2016) and Statcounter (n.d).

6.1. Digital platforms in Zimbabwe

A digital platform is **a** place for exchanges of information, goods, or services that occur between service providers, producers, consumers as well as the community that interacts with the said platform. The commonly used digital platforms in Zimbabwe include social media platforms like Facebook and media sharing platforms such as YouTube. As of 2020, Zimbabwe's use of social media stood at 13 percent of the population (Digital, 2022), with Facebook getting the biggest share (Statcounter, n.d[10]). According to FAO and ITU (2022), in-bundle data usage constituted 91.8 percent of total mobile Internet. WhatsApp usage constituted 40.5 percent of total mobile Internet and data usage, followed by YouTube at 11.4 percent and Facebook at 2.4 percent.

Some of these platforms are a result of public-private-partnership, for example, the Kurima Mari app (mobile app used for money transactions) where the Ministry of Agriculture in partnership with Zimbabwe Farmers Union and Welthungerhilfe (WHH) a non -governmental organisation developed a mobile app where farmers can interact virtually, access extension services, market information and also carry out the virtual transaction.

Through the extension program, the Government has been promoting climate-smart agriculture farming concepts such as Pfumvudza Conservative farming concept being adopted by smallholder farmers. Electronic

[10]Social Media Stats Zimbabwe Feb 2021 - Feb 202; https://gs.statcounter.com/social-media-stats/all/zimbabwe accessed as at 19 March 2022

transition through banking applications and mobile money platforms such as Eco cash, one wallet, and telecash have been widely adopted in the country. Digital applications/ infrastructure, availability; access and utilization.

Growth in Financial payment platforms. Zimbabwe has witnessed a rise in the number of financial payment platforms which include Ecocash (Econet), One Wallet (Net one), Telecash (Telecel), Inn Bucks (Innscor) and My Cash. According to the Reserve Bank of Zimbabwe (2022) there has been an increase in both volume and value of transactions carried out through mobile payment platforms.

6.2. Digital technologies and gender

The proportion of female and male active mobile subscribers stands at 41.3percent and 58.7percent respectively in 2021 (POTRAZ, 2021).[11] The gender imbalance in access to mobile phone service, disadvantages women who form the majority of the labour force in agriculture sector as this limits their access to information, and reduced adaptive capacity. Access to and use of telephone technologies will have a greater impact on women's ability to adapt to the climate.

Access barriers, affordability, a lack of education, as well as inherent biases and socio-cultural norms limit women's capacity to benefit from digital technologies. Furthermore, women's lower educational enrolment in disciplines that would enable them to perform well in a digital world (e.g., science, technology, engineering, and mathematics [STEM] and information and communication technologies [ICTs]), combined with women's limited use of digital tools and the relatively scarcer presence or activity on platforms – e.g., for business purposes – suggest a potential scenario of widening gaps and greater inequality. Policy, particularly in the form of coordinated and complementary efforts, has the potential to reverse these trends and set the stage for a more inclusive path based on closing digital and gender disparities. Raising awareness and combating gender stereotypes are required to close the digital gender gap, as well as providing improved, safer, and affordable access to digital tools and fostering strong collaboration among stakeholders to remove barriers to women's full participation in the digital world (Organisation for Economic Co-operation Development, 2018).

Digital technologies such as the internet, mobile phones and digital financial services offer opportunities for women to earn extra income, increase employment opportunities and access knowledge and information. As such, platforms such as online or video-based up skilling and tutorials may help women make better use of the digital tools and extract more value from them. Compulsory ICT training in schools would help to eliminate the digital gender divide. Raising awareness about education opportunities is key for women. For instance, some online courses can be accessed for free and cover a range of topics. Removing obstacles to adult education is also key because it provides more opportunities for adults to upgrade their skills (Organisation for Economic Co-operation Development, 2019).

6.3. Potential avenues for the public sector

The public sector has an important role in the creation of an enabling environment that allows scaling of digitalization. The public sector plays an important role in the development of National Adaptation Plans that will drive the adaptation process. Different public service organisations, and public-private partnerships can be used in the implementation of specific adaptation projects for example the ZAKIS project[12].In view of the frequent occurrences of drought floods epidemics, cyclones food insecurity, animal and plant diseases,

[11] For additional information see https://www.itu.int/en/council/cwg-internet/Pages/display-oct2017.aspx?ListItemID=34 ; https://link.springer.com/chapter/10.1007/978-3-030-58240-1_3

[12] ZAGP website; https://zagp.org.zw/projects/view/research-education-and-extension

Government set up the Civil Protection Unit(CPU) which is responsible for managing all disasters in the country. This relies on information and data for it to prepare, respond, prevent, mitigate, rehabilitate, recover, and restore. Digital technologies will greatly enhance the work of the CPU. The Metrological Services Department (MSD) is responsible for weather forecasting in Zimbabwe. MSD has both digital and manual weather stations in the country. There is a gravitation towards digital localised weather stations as they provide more accurate data.

6.4. Potential avenues for the private sector

The private sector accounts for 85percent of all investments worldwide, 90 percent of people in developing countries depend on private sector generated income and represents close to 75 percent of global climate finance flows (FAO and ITU, 2022).[13] Therefore, the private sector can play a big part in providing financial resources for adaptation through investments, financial risk management, and the commercial provision of capital and the philanthropic provision of resources through private foundations. Lead the digital climate change adaptation through investing in the ICT infrastructure, launch telecommunication services that ensure affordable access to information for all. They can also fund other sectors that support the digitalization process for example renewable energy. Through partnerships, there are opportunities for technical expertise and innovation transfer (World Bank, 2019).

7. Challenges and opportunities for digital adaptation in Zimbabwe

7.1. Challenges for expansion of digital adaptation solutions

Digital infrastructure is one of Zimbabwe's relative strengths, however regulatory roadblocks and macroeconomic conditions hamper its growth. Zimbabwe's international connectivity infrastructure is relatively well-developed with optical fibre connecting major cities and urban areas. However, large gaps remain in rural areas hence inequalities in access or information and as a result, adaptive capacity between well serviced and those not services differ. Aging infrastructure and insufficient resourcing, combined with overall macroeconomic distress, electricity, and connectivity issues, are major bottlenecks.

The mid-Zambezi basin communities are being impacted severely by climate hazards such as droughts, floods, high temperature and erratic rainfall patterns, therefore, digital climate adaptation offers an opportunity to achieve food security. However, most of these people cannot afford these digital technologies therefore awareness campaigns need to be coupled with strategies that enable these farmers to access the technologies and improved ICT infrastructure that is currently not sufficient. There is a need for capacitation of key organisations such as the Civil Protection Unit (CPU) with the ideal equipment for improved data generation and reporting. There is a need for a digital skill capacitation program so as to ensure the success of the transformation program.

The availability of affordable cheap phones is giving women an opportunity to own phones and get equal access to information and enhance their preparedness. Strategies need to be put in place for access to a wide range of digital tools including computers, GPS gadgets, and tablets among others to complement smartphones. Through scaling adoption of digital tools, there are many opportunities that can be derived apart from delivering information, data collection can also be done, and this makes it faster and cheaper. To encourage adoption

[13] For additional information see https://www.fao.org/3/cb7943en/cb7943en.pdf

there is a need for all stakeholders to be involved, the Government can promote local production of some of the ICT equipment.

Through the country's goal to achieve an upper middle-class economy by 2030, digitalization is a key component in the achievement of this goal. Zimbabwe needs to make regulatory improvements as well as investments in four interconnected areas across all pillars: policy and regulatory framework, resource management and coordination, governance, and capacity building. Much work remains to be done both on fixing the macroeconomic fundamentals, and yet these also create an opportunity for leapfrogging and incentive for further innovation, just as the case of digital financial services illustrates. The lack of digital literacy needs to be addressed at the academic level through the inclusion of ICT in the curriculum complemented by professional digital training that can be offered in schools and within companies through on the job training programs.

Constraints towards adoption of digital technologies in climate change adaptation

The major challenges limiting the adoption of digital technologies in climate change adaptation in agriculture in Zimbabwe that emerged from the consultation workshop include the following:

i. Capacity challenges – Low capacity of smallholder farmers to generate and process data and effectively use the information required to strengthen them to maximize benefits from the use of the technologies. Also, there are capacity challenges in terms of skills to install and operate the digital adaptation technologies.
ii. Unavailability and Immature technologies – The agriculture sector has a number of digital technologies under pilots, but smallholder farmers are hesitant to adopt and use them. In addition, some of the suitable technologies, applications, software systems and platforms for data-driven agriculture and precision farming are just emerging and not readily available in the country. Some of the technologies require high computer literacy skills which most smallholder farmers do not have e.g., artificial intelligence.
iii. Access barriers and lack of information on available technologies – Most farmers are excluded from some of the technologies because of lack of information about the technologies and their benefits.
iv. Data challenges –digital technologies rely on data to provide the required output. There is limited capacity to obtain climate data at the local level hence challenges in using the technologies. A lack of partnerships between different stakeholders and ensuring coordination, accurate and advanced climate modelling and forecasting capacities.
v. Requirement of high levels of climate literacy is also another challenge for digital adaptation. Some farmers are not comfortable using digital technologies as they look complicated.

Poor coordination

There is general poor coordination among stakeholders involved in digital technologies for climate change adaptation. This results in duplication and wastage of resources. Sharing of telecommunication infrastructure will result in reduced costs to the end users. Poor coordination also results in unnecessary competition between players which in some cases does not benefit the final consumer. Licensing authorities should better coordinate well to have investments spread across all areas i.e., urban and rural.

Policy Constraints

Governements, Private sector and Development partners may push for increased use and adoption of digital adaptation tools, hut however policy constrains such as power and internet connectivity may militate against the aspirations or ambitions. The National Cyber Security law, which allows government to incept private

communication for national security is constraining investment in digital technoloigies as some investors are reconsidering investment options (MISA Zimbabwe 2021) [14]. Also, State companies are perceived to enjoy preferential treatment from Government in terms of taxes and other incentives. The state controls data and call charges which is creating viability challenges for some of the companies in the sector hence acting as a barrier to further investments in the area.

7.2. Opportunities for expansion of digital adaptation solutions

Zimbabwe has major opportunities to expand digital solutions as shown by the importance of digitalisation in the achievement of vision 2030. A lot of private organisations are actively involved in scaling the much needed digital infrastructure. The GoZ has created an enabling environment for ICT development through the removal of restrictions on entry in investing in the ICT sector as shown by the growth and rise in the number of telecommunication companies in the country. The high number of active ICT companies offers a competitive environment to improve the quality of service delivery. The Government has waived duty on components used in the ICT sector to reduce infrastructure and operational costs. This is expected to have ripple effects and reduce data and voice call charges to consumers. It has also created the Universal Service Fund (USF) which is financed by taxes and charges on data, message and voice calls. The funds are reinvested into the sector to improve its operating efficiencies and hence reduce the cost of data. Also Governement through the Rural Electricfication Programme is expanding access to electricity in rural and other marginalised areas to enable access to electricity and also power household appliances including those for digital technologies.

Despite such a competitive environment, there are disparities in service provision across the provinces. The mobile companies are operating in all the provinces and in most rural areas including the Zambezi River Basin. Coverage is not 100percent as there are some dead spots where connectivity is not available. However, as a result of the unstable macroeconomic environment, there has been slow growth in the digitalisation processes, and this has been observed across the whole country. Econet Wireless, the leading telecommunications company launched 5th Generation (5G) network technology in Harare in February 2022.

The energy gap characterized by insufficient energy production leading to power cuts contributing to the slowed growth in all sectors including the digitalization process. Therefore, for the success of digitalisation process there is a need for optimisation of key areas such as energy production, and address the unstable macroeconomic environment so as to encourage foreign direct investment. Inadequate financing of sound budget allocation leads to the private sector playing a minor role in ICT infrastructure development hence the slowed growth in the ICT sector.

The Government through various ministries is also rolling out the digitalisation program through e-Government services, online service delivery, e-public services, e-revenue, and one-stop service, and/or integration of all Government services to citizens and businesses. Due to the COVID-19 lockdown restrictions, these platforms allowed virtual interaction and hence played a big role in reducing the spread of COVID-19 and continued access to resources and services.

The following were identified as opportunities for upscaling of digital technologies in the country:

[14] An analysis of the recently gazette Data Protection Act of Zimbabwe. MISA Zimbabwe, 6 DEC, 2021; https://zimbabwe.misa.org/2021/12/06/analysis-of-the-data-protection-act/https://zimbabwe.misa.org/2021/12/06/analysis-of-the-data-protection-act/

a. There are already existing technologies and software platforms e.g. Google maps, Facebook, YouTube, Twitter, LinkedIn and Instagram. The programme can ride on these digital technologies.
b. Advanced Mapping of existing communication systems, functional state, number and coverage
c. Make use of advanced software available in the country for example upgrading existing weather stations to use advanced software.
d. Investment and increase in capacity building of most personnel involved in weather forecasting to be able to use big data in weather analysis and increase the number of automatic weather stations for data collection.
e. Use of SMS platforms for weather and agronomic advisories information dissemination communication on climate change adaptation and these can be scaled up to cover as many smallholder farmers in the Zambezi basin as possible.
f. Expansion and accelerated implementation of the Rural Electrification Programmes to power the digital technologies.
g. District authorities have Disaster Risk Management plans which can be achieved through use of digital technologies to predict occurrence or non-occurrence such as droughts, cyclones and floods.
h. Development partners are already investing in digital technologies and hence can ride on these investments.
i. Fewsnet and WFP are using digital technologies in tracking disasters such as floods and droughts and these successes can be up upgraded and scaled.

Opportunities for investment in digital climate-smart technologies

The Government through macroeconomic stabilisation can also create an environment that attracts investors and development of ideal policies that can drive climate adaptation and mitigation. Currently, there is low budget allocation to climate change adaptation and digitalisation. Therefore, the private sector has to step in, the Government can promote this through subsidies and tax rebates. Through accessing funds such as the Green Climate Fund, Global Environment Facility, Adaptation Fund and the Universal Service Fund the Government can acquire and upgrade the digital infrastructure that is able to generate the information required by stakeholders in decision making. Climate financing allows vulnerable communities that would otherwise not afford various technologies to be able to access the required technologies. Climate financing can also be done through public-private or private-private partnerships, and these are key not only in generating funding but also in technical and innovation transfer that are lacking in smallholder communities. Some of the digital technologies that require financial investement are summarised in Table 15.

Table 15: Opportunities for expansion of digital adaptation solutions

Components	Purpose	Example Applications	Success
1. Digital output instruments (weather stations, computers, smartphones, Early Warning Systems, E-Extension)	To collect and transmit information in real time	Rain gauges, flow meters, water quality monitoring and other environmental data	High adoption at the farm level
		Acoustic devices for real-time leakage detection	Not highly used
		Video camera for asset management	Very highly used on high price real estate such as affluent neighbourhoods and business properties
		Smart water meters for measuring consumption	Highly used with all water supplied by municipalities being measured
		Pressure monitoring for leakage detection and pump optimization	Not highly used

2. Supervisory control and data acquisition (SCADA) systems	To process information and remotely operate and optimize systems and processes.	Pressure management	Average usage
		Pump station optimization	High usage
		Water treatment plant control	Implementation phase
		Sewage treatment plant control	Not well used
		Environmental controls, reservoirs, flows, etc.	Implemented and enforced by many organisations such as ZINWA
3. Geographic information system (GIS/GPS) and Remote sensing	To store, manage, manipulate, and analyse spatial information.	Asset mapping and asset management	Usage is on the rise though not so much at the smallholder level
		Fully integrated network models	Usage is increasing
		Environmental data analysis and management	Implementation is done, weak management
		Usually integrated with GIS and/or SCADA systems to manage water networks, control pressure, monitor leakage, etc.	On the rise promoted by research institutions and the private sector
		Improved decision making and risk management	
		Customer databases	On the rise
		Smart metering, billing and collections	Widely used especially in urban areas, implemented by municipalities
		Hydraulic design and optimization	In use mainly at tertiary institutions
		Water resources and hydrological modelling for water security	Minimum usage
		Cloud-based data management and hosting options	On the rise at personal, organization and at national level

Source: Authors Illustration

Enablers to investments

There is a need for investment in enabling infrastructure which includes:

Energy - is important as most technologies are powered by electricity hence it is critical that power is provided.

Road infrastructure - installed infrastructure needs to be accessible hence the requirement for good roads in rural areas or Zambezi basin

Security – theft is rampant in most rural areas and there is a need for adequate security to guard against this. All the investments may be vandalized and made unusable through the theft of key components;

Access to suitable and affiordable finance – enables the necessary investements to be done in the ICT sector. This will be used as launch pads for the Climate Change digital adaptation tools; and

Other services –servicing facilities for the equipment should be available locally preferably in main centres. This will greatly reduce operational costs.

SWOT analysis on the scaling of digital climate change adaptation technologies

In order to understand the challenges and opportunities in the scaling of digital climate change adaptation technologies a SWOT analysis was undertaken. Table 16 summarises the results of the SWOT analysis of digital technologies adoption and use in the agricultural sector.

Table 16: SWOT analysis on scaling of digital climate change adaptation technologies

Strength	Weakness	Opportunity	Threat
• Availability of climate change adaptation polices • Introduction of affordable ICT technologies • Development partners working in collaboration with Government and rolling out digital technol;ogies such as Kurima Mari, Zim Agric Exyension App • Mobile money services available e.g., ECOCASH promoting electronic transaction and Ecofarmer • General interest of people in digital technologies • Good rates of adult literacy • Strong penetration of mobile banking and mobile networks • Zambezi basin has wide biodiversity that attracts investment through tourism • Digital weather stations being introduced by the Zimbabwe Resilience Building Fund	• Policies are housed in various ministries hence room for contradictions and replication • low Government budget allocation towards ICT • Low levels of foreign investments in the country • Energy gap resulting in areas with no access to electricity or high rate of power cuts • high price of digital technologies • High taxes make goods and services unaffordable • Low ICT literacy levels among rural population especially women • Fragmented service provision by both services in public and private sectors • limited awareness contributing to limited access to technologies • Poor mobile network coverage and poor road networks in rural areas • Fewer mobile service providers	• Rural population 70% of the total population • Basic ICT infrastructure already available (Strong internet and mobile infrastructure upgrading ongoing e.g., launching of 5G) • Tax rebates for organization investing in digital infrastructure • Establishment of Innovation Hubs at universities and research centres • Expected macroeconomic stability • General interest in Digital technologies • Population growth and youth share of the population • importance of smallholder farmer contribution to GDP • high interoperability of ICT infrastructure • Potential of digital technologies in decision making • Opportunities for use in climate smart agriculture	• Weak regulatory frameworks • Unstable macro-economic environment • weak climate financing systems • high ICT and mobile data costs • Vandalism of ICT infrastructure high • Booming cybercrime industry that has the potential to undermine trust in digital solutions • Gender gap in ICT literacy • Damage to ICT infrastructure due to climate hazards • Lack of ICT skilled labour

Source: Authors Illustration

7.3. Recommendations for the actionable design of technologies and engagement opportunities

Successful implementation of digital climate adaptation is centred on creation of an enabling environment driven by policies that are relevant, well harmonised and gender-inclusive. There is a need for capacitation of human capital and equipment for effective data collection and effective communication. Stabilisation of macro economy is very fundament in the implementation of a sustaining e digital climate adaptation. This is important in attracting investments that address major challenges threatening the digital climate adaptation transformation process such as investment in renewable energy, ICT infrastructure upgrade and improving coverage. The cost of investing in digital technologies is deterring adoption, there is a need to promote locally produced technologies that are affordable. As a result, the Government and private sector need to upscale funding of research and technology development through the innovation hubs that have been already set up. This will ensure the accessibility, availability and affordability of digital technologies to enhance the adaptive capacity and resilience of communities in the Zambezi basin. Furthermore there is need to disaggregate the interventions to address the constraints towards digital technology adaptation into those that focuses on the farmers directly and those affecting the farmer support systems.

During the consultation workshop, participants managed to identify and recommended technologies for climate risk adaptation as summarised in Table 17.

Table 17: Digital technologies and constraints to adaptation

Technology	Constraints	Recommendations
Short Term		
Early Warning Systems	Access to modern gadgets (smartphones, computers, cameras) and software	Facilitate access to digital technology gadgets and last mile dissemination of information to farmers
		Provide Capacity Buidling to key Institutiosn such as Extension departments and Meterologial Services Department to enable them to provide precise and user friendly climate data
E-extension/advisory technologis	Non availability of suitable technology in smallholder areas	Invest in R&D in appropriate technology and have a strategy for deployment in smallholder farming areas.
	Farmers cannot afford smartphones that allow them to access digital applications	Facilitate access to digital technology gadgets to enhance access to E-extension services.
		Training of farmers extension officers and media personnel on interpretation of information from automated weather stations
E- markets /E-commerce	Limited or no access to e-markets due to unavailability of ICT gadgets such as computers and smartphones	Provide digital technology equipment including computers, smartphones and printers
	Limited access to internet data	Revise internet data tariffs to be affordable as well as subsidizing the cost of ICT data for selected smallholder farmers.
E-mobility	Limited availability of the technology	Promote importation of the technology through subsidies and tax incentives.
	Cost of the technology too high for smallholder farmers	Provide innovative ways of funding the technology including subsidies, development financing etc.
Medium Term		
Websites, blogs and social media	Limited connectivity due to unavailability of network Limited availability of computers, smartphones and	Invest in expanding coverage in the Zambezi river basin
		Reduce or remove taxes in the importation of computers and smartphones into the country

	other gadgets to access these services through the internet service	Promote local production of computers and ICT accessories
Automated Teller Machines (ATMs) , banking and Finance	Limited access to ATMs as they are located mainly in growth points, towns and city centres.	Invest in decentralising banking services, have ATMs at local centres
	Most ATMs are non-functional due to intermittent internet connectivity	Invest in internet connectivity infrastructure
		Invest in alternative source of energy such as solar so that ATMs are continuously powered
Drone	High cost of technology	Support production of cheap /affordable drones at the country's innovations hubs
	Restrictive policies on the use of drones	Lobby for policies that promote and support use of drones for digital adaptation.
Community radio, Television (TV)	Unavailability of radio and TV signal in some areas.	Invest in improving radio and TV signal transmission infrastructure
	Limited ownership of Smartphones, computers, TVs, radios and TVs in rural areas.	Reduce import duties on radio and TV sets
		Support introduction of community halls were there a/re community TVs and radios
		Incentivise private sector investment in the production of TVs and Radios in the country
Insurance Weather indexed insurance	Limited adoption of weather indexed insurances by farmers due to lack of information on the importance of insuring crops and livestock.	Increase awareness campaigns and communication to inform farmers on the importance of weather insurance and its importance to agriculture.
		Incentivise insurance firms to develop innovative weather insurance products to promote adoption.
		Provide incentives to insurance to invest in rural weather indexed systems.
GIS and GPS	Outdated and obsolete equipment which gives inaccurate results	Invest in modern GIS and GPS equipment.
		Encourage private sector investment in the development of GIS and GPS infrastructure.
Video Streaming	High cost of internet connectivity (requires high bandwidth)	Invest in ICT infrastructure such as base stations and fibre optic cables to lower the cost of data
Long Term		
Mobile and fixed telephones	Farmers cannot afford smartphones that allow them to access digital applications.	Invest in R&D in appropriate technology that facilitate farmers access to smartphones
	Non- availability of telecommunication infrastructure.	Invest in additional telecommunication infrastructure such as base stations, optic fibre and equipment servicing facilities.
		Expand fixed network infrastructure to remote areas
	Cost of data too high	Promote infrastructure sharing to lower the operational costs hence reduction in the costs of voice calls/ data
Robotics	Non availability of suitable technology in smallholder areas	Invest in R&D in robotics technology and have a strategy for deployment in smallholder farming areas.
Self-scanning machines and printers	Access to the technology is limited	Invest in community information kiosks were these services are available.

7.4. Summary and Conclusion

Zimbabwe continues to face dry spells, droughts, rising temperatures floods and these have made farming costly over the time hence there is a need for action. It was highlighted that digital technology can play a major role in climate change adaptation in Zimbabwe. A number of digital technologies needed for climate change adaptation ranges from improving production at the farm level, to marketing and receiving climate related information. There is an understanding that whilst these technologies are needed, they are associated with costs to do with acquiring these technologies. The Government of Zimbabwe has responded to climate change issues through a number of initiatives such as the Pfumvudza program on climate change and innovation hubs in some of the universities to strengthen and upscale the use of digital technology, whilst the private sector has developed innovative applications that allow farmers to access information related to climate hazards and market information. Furthermore, there is a need for innovating financial mechanisms, because access to finance is a key constraint for adaptation to climate change.

Digital adaption varies greatly along the value chain. Due to limited resources, adoption of digital tools is low, especially in smallholder production systems yet they form the majority of the farming system. To address the challenges at the production level a lot of work needs to be done to increase awareness and capacity building such that they can adopt the climate-smart technologies that will increase productivity within the farming system without the need for expansion of agricultural land. The use of e-extension with messages and training delivered via SMS, videos, TV, radio program will increase awareness and adoption of technologies. However, limited funds to invest in digital technologies may result in low adoption despite high awareness. The values chain digital tools are more involved in the efficient processing and delivery through automation. As a result of the unstable macroeconomic environment, the cost of investing in digital tools is contributing to low adoption for example whilst smallholder farmers understand the need to adopt irrigation system, the cost of investing is too high, coupled with a lack of title deeds and these farmers cannot use the land as collateral security when accessing loans. Some of the major players in the digitalization process are various ministries including agriculture, environment and ICT and tertiary institutions. The Government through POTRAZ regulates the ICT industry in Zimbabwe, public telecom companies such as Telone. The majority is dominated by private players such as Econet wireless, Telecel and Liquid other liquid intelligent technologies.

Table 18 presents digital technologies ranking by stakeholders the validation workshop. A number of factors were considered in ranking the technologies including current use, availability, cost among others. The ranking is inorder of priority.

Table 18: Ranking of digital techonologies

Ranking	Technology
1	Digital Climate Services and Early warning systems
2	Community Radio and TVs
3	Mobile and fixed telephones
4	E-advisory services
5	E-mobility
6	Automatic rainfall stations
7	Remote Sensing
8	E-market/E-commerce
9	Geographic Information Systems and Global Positioning Systems
10	Natural resources management technologies (e.g. digital animal trackers, soil moisture meters, chameleon sensors)
11	Index-Based Weather Insurance
12	Drone Technology
13	Artificial Intelligence (AI) and Robotics
14	Block Chain Technology

Source: Validation workshop, 28 April 2022

Table 19 provides information related to key constraints. This scorecard summarizes the constraints of adoption of these technologies.

Table 19: Digital apps scorecard

Digital technology	Constraints	Score
Early Warning Systems	Access to gadgets and software	1
E-government, E-learning, E-extension and E-commerce	High cost of data	2
Global Positioning System (GPS);	Lack of technical skills, lack of requisite gadgets	3
Automated Weather stations;	Lack of gadgets	4
Mobile platforms; such as E-advisory services	Limited infrastructure	5

Source: Stockholder consultation workshop held March 08, 2022

7.5. Some proposed interventions for Zimbabwe

Table below provides some proposed interventions for implementation in Zimbabwe. Further refinement can be done at implementation stage.

Table 20: Proposed interventions at the Country Level-for Zimbabwe

Interventions areas	Knowledge & Analytics	Investment in middleware infrastructure	Capacity building
Development of Digital Climate Services	• Strengthen National Adaptation plans by mainstreaming Digital Technology therein . Develop a Digitization policy with a focus on climate adaptation	• Develop national integrated database management system for climate data collection and analysis for dissemination to avoid confusion in messaging. • Zimbabwe Meteorological Department needs investments to properly equip it with automated weather stations-currently these are few	• Provide tr warning s knowledg implemer • Provide tr Departme weather p
Facilitating access to advisory services and markets through digitalization	• Develop climate science communication mechanism in Zimbabwe that use all local languages and integrate these in mobile applications for climate information dissemination. Currently some languages not covered	• Develop geological maps that summarize crop, soil, and rainfall information in each location • Expand telecommunications infrastructure, eg mobile towers • Promote business models that target rural women farmers with low cost smart mobile phones, and innovative financing , through cooperatives	• Train mec interpreta from wea • Provide tr on interp
Promotion of Climate-smart innovations and technologies	• Ensure that relevant digital technologies (eg drones, smart phones to farmers, internet equipment) are exempted from import duties and taxation	• Increase the number of functional Automatic Weather Stations in Zimbabwe • Reduce taxes/import duties on key adaptation technologies, eg smart phones, drones, irrigation sensors etc	• National t climate-sr adaptatio

Promote Natural resources management	• Promote awareness among farmers on the importance of technology use in farming and climate adaptation eg chameleon sensors for irrigation	• Equip Universities with remote sensing and AI software to be used in teaching • Introduce digital animal trackers, soil moisture meters, chameleon sensors to improve agricultural productivity and thus adapt to climate change	• Provide tr to monito availabilit • Introduce Zimbabw

Table 21: Digital Technology and constraints

No.	Technology	Constraints	Target Beneficiaries
1.	Mobile and fixed telephones (Delivery medium for technologies)	• Lack of affordability for smart phones to access digital applications. • Non- availability of telecommunication infrastructure. • High cost of mobile data	Farmers and all value chain actors
2	Websites, blogs and social media (Delivery medium for technologies)	• Limited connectivity due to unavailability of network • Limited availability of computers, smartphones and other gadgets to access these services	Farmers and other value chain actors

3	Drones (Technology)	• High cost of technology • Restrictive policies on the use of drones	Farmers, Value chain actors
4	E- Mobility (Technology)	• Limited availability of the technology; • Cost of the technology too high for smallholder farmers	Farmers and all value chain actors
5.	Community radios and Televisions (Delivery medium for technologies)	• Unavailability of radio and TV signal in some areas. • Limited ownership of radios and TVs in rural areas.	Farmers and all value chain actors
6.	Weather index insurance(Technology)	Limited adoption of due to lack of information on the importance of insuring crops and livestock	Farmers/insurers
7.	GIS and GPS(Technology)	Outdated and obsolete equipment	Farmers and other value chain actors
8.	E-market/E-commerce(Technology)	Limited or no access to e-markets due to unavailability of ICT gadgets such as computers and smartphones Limited access to internet	Farmers and other value chain actors
9.	Video streaming(Delivery medium for technologies)	High cost of internet connectivity (requires high bandwidth)	Farmers and extension officers

10.	Automated Teller Machines (ATMs) /banking (Delivery medium for technologies)	Limited access to ATMs in rural areas. Limited access to ATMs due to intermittent internet connectivity	Value chain actors
11.	Robotics(Technology)	Non availability of suitable technology in smallholder areas	Farmers and other value chain actors
12.	Self scanning machines and printers(Technology)	Limited accessibility	Value chain actors

Table 22: Top 5 recommended technologies

Focus of Technology	Technology /Delivery Mediums	Where to invest in	Responsibility
Specialised information provision	Global Positioning System (GPS) (Technology)	Gadgets, Capacity strengthening	Public and private sector
Provision of weather-related information	Automated Weather stations (Technology)	Digital weather gadgets,	Public and private sector
Transactions, information dissemination	Mobile platforms (Delivery medium for technologies)	Mobile platform infrastructure	Public sector
Information dissemination	Community radios; and televisions (Delivery medium for technologies)	Base stations, purchase of radios and TVs	Public and private sector
Extension services provision, Market information	E-government, E-learning, E-extension and E-commerce (Technology);	Mobile platforms infrastructure, base stations	Public and private sector

Source: Project Consultative Workshop-Zimbabwe, held on March 8th, 2022

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Annex 1 – Case studies from Zimbabwe

A1.1. Famine Early Warning Systems Network (FEWSNET) Early warning system

The Famine Early Warning Systems Network (FEWS NET) is a leading provider of early warning and analysis on acute food insecurity around the world. FEWS NET provides unbiased, evidence-based analysis to Governments and relief agencies who plan for and respond to humanitarian crises. FEWS NET analyses support resilience and development programming as well. Through the early warning systems, it allows detailed mapping and reporting current and projected food insecurity, Alerts on emerging or likely crises, Special reports on factors that contribute to or mitigate food insecurity, including weather and climate, markets and trade, agricultural production, conflict, livelihoods, nutrition, and humanitarian assistance. This has become more important as the projected climatic changes show high levels of food insecurity therefore this tool informs and guides decisions such that the impact of famine will be minimised. The Zambezi basin is one area frequently affected by famine, to reduce the vulnerability of people in the area, use of this tool will go a long way in improving the resilience of these communities by ensuring they are well informed. The information will guide and influence adaptive capacity through adoption of climate change adaptation technologies.

A1.2 Kurima Mari farming application

The Kurima Mari farming app offers a one stop platform for farmers to interact virtually. Farmers can access inputs and other services such as specific information on crops, livestock through direct links to experts and access to markets. A tool like this of great importance for example with the COVID-19 restrictions farmers can still get access to markets and information they need without physical integration. To access the platform, one need a smart phone, register on the app and skills to navigate on the platform downsize is the farmer is you need a mobile phone and the App is available on Google play store; hence everyone can access it including women.

A1.3 Eco Farmer: One stop shops for farming services including weather index-based insurance

Eco Farmer App offers one stop shop to farmers as it allows them to access information on farming inputs, market and extension services such that farmers can increase productivity. Climate change is impacting on the agriculture sector through climate hazards that have resulted in crop loss through floods or droughts and dry spells. Farmer have an opportunity to ensure their crop through the Eco Farmer app such that they can get compensation in the event of crop loss as a result of climate hazards. The subscription is very low therefore farmers can afford to insure their crop. Eco Farmer is provided Econet one of the biggest network providers in the country with the highest SIM card subscription therefore all the farmers using Econet services can register to the weather index-based insurance. In the event of crop loss farmers are compensated such that they can recover quickly compared to non-insured farmers. Coupled with other services offered by Econet such as electronic transactions such as the Ecocash service that has been very important as cash transaction are not always possible. Farmers can now make payment and receive payments in the comfort of their home leaving them more time to concentrate on farming hence increasing chances of improving productivity.

A1.4 Radio Programmes

Radios have for very long time been used to convey information through national radio stations that have wide coverage. However, the main challenge was they could not cater for all the local languages therefore the minority languages were not fully represented in the content for example Tonga language which is common in Binga area long the Zambezi River. With the launching of community radios farmers now have access to information that they can relate and understand clearly through use of the languages in that

community. This goes a long way in ensuring farmers understand the messages such that implementation of recommendations becomes easier. Radios vary in size with some that can be powered by batteries such that even farmers that are in areas that don't have electricity can still access the information. Radio can also be accessed through mobile phones and these are some the advantages that ensure wide coverage. However, the radio lacks visual display therefore people that understand better through visual display maybe left out. The older generation trust the radio so through conveying climate change adaptation methods through the radio one is guaranteed of wide coverage of farmers in this age group.

Small holder farmers as result of having very little disposable income and resource poor cannot afford to buy some of the equipment. Therefore, through this platform therefore contribute to spoilage of produce and poor post-harvest management practices.

Annex 2: Key Regional Stakeholders

Name	Role/Focus
Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL)	Research and Capacity
United Nations Development Programme (UNDP)	Financing
International Water Management Institute (IWMI)	Research and Financing
International Institute of Tropical Agriculture (IITA)	Research and Financing
African Development Bank (AfDB)	Financing
Global Center on Adaptation (GCA)	Research and financing
Zambezi Watercourse Commission (ZAMCOM)	Research
USAID	Financing, capacity strengthening
Southern Africa Development Community (SADC)	Research , policy development
Common Market for Eastern and Southern Africa (COMESA)	Research , policy development, capacity strengthening
Food and Agriculture Organization of the United Nations (FAO)	Research and Financing
Center for Agriculture and Food Policy (CAFP)	Research , programme implementation and capacity strengthening

Annex 3: Stakeholders Consulted

Name	Sector
Meteorological Services Department (MSD)	Government
Ministry of Lands, Agriculture , Water, Fisheries and Rural Development	Government
Ministry of Environment, Tourism and Hospitality Industry	Government
Infrastructure Development Bank (IDBZ)	Government
Zimbabwe Resilience Building Fund (ZRBF/UNDP)	Development Partner
Practical Action	Non-Governmental Organisation (NGO)
Scientific and Industrial Research and Development Centre (SIRDC)	Government/ Research Institution
Net one	Private sector
Reserve Bank of Zimbabwe (RBZ)	Government
COSV	Non-Governmental Organisation (NGO)
World Food Programme (WFP)	Development Partner
Zimbabwe Farmers Union (ZFU)	Private Sector
Food and Agriculture Organisation (FAO) of the United Nations	Development Partner
Agriculture Marketing Authority	Government
Ministry of Energy and Power Development	Government
Civil Protection Unit (CPU)	Government