Drought Hazard Risk and Humanitarian Impact Analysis and Inventorisation of Forecast Models in Zimbabwe

FORECAST BASED ACTION – Drought Hazard Risk and Humanitarian Impact Analysis

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EXECUTIVE SUMMARY

Zimbabwe is a country located in the subtropics and very vulnerable to climate shocks. With the advent of climate change, studies predict that the climate will become drier with increased intensity and frequency of droughts. Zimbabwe's economy is agro-based. The GDP is largely driven and derived from the processing of output from the agricultural sector. Furthermore, the largest proportion of Zimbabwe's population (70%) resides in rural areas where they are dependent on agriculture for their livelihoods. The staple crop is maize, and it is widely grown throughout the country primarily for food. Other cereals include small grains (sorghum and millets), which are mostly grown in the drier regions of the country. Tobacco, cotton and horticulture are the main commercial crops and are the top earners of foreign currency within the agricultural sector. Agricultural production is predominantly rain fed (>97%), which makes it very vulnerable to rainfall pattern. Droughts erode the livelihoods of the people, exposing them to hunger, malnutrition, loss of safety nets including livestock, reduced incomes, shortage of safe drinking water, which all drive people deeper into poverty. This makes it very difficult for the country to eradicate poverty and attain developmental goals such as the Sustainable Development Goals. In fact, drought is the single most important natural disaster that the country suffers. It is therefore important to develop systems that make the country more prepared to deal with droughts. Part of this includes development of reliable drought forecast models, and strong response mechanisms to reduce the humanitarians impacts such as food insecurity in the event of drought. This study is motivated by the need to develop Scientific Drought Forecast Trigger Models and to take stock of the humanitarian impact of droughts in Zimbabwe. This study aims to deliver an updated and comprehensive (i) analysis of drought hazard risk and humanitarian impacts and (b) inventory of existing drought forecast models. Key informant interviews with National, Provincial and District Level government officers were conducted, and secondary data were also solicited to establish trends in changes in key indicators as caused by drought.

Key highlights of findings

Drought risks are characterised as follows:

- *The timing and amount of rainfall received are becoming increasingly uncertain*
- *The last four decades have shown a trend towards reduced rainfall or heavy rainfall and drought occurring back to back in the same season.*
- *Shifts in the onset of rains, increases in the proportion of low rainfall years, and increases in the frequency and intensity of mid-season dry-spells have been observed*
- *The frequency and length of dry spells during the rainy season have increased while the frequency of rainy days has declined*

Despite the evidence of climate change, the use of seasonal climate forecasts and early warning signals to trigger pre-defined anticipatory actions is very limited in Zimbabwe. The assumption is that with access to seasonal weather forecast, smallholder farmers are likely to plan and take remedial actions prior to a drought risk in order to mitigate the anticipated impact on food security, lives and livelihoods

Impact on Agricultural Production

Droughts have a strong and negative impact on production of crops and livestock, and consequently on GDP for Zimbabwe. With climate change the predictions are that due to reduced moisture and increased temperatures, yields of staple crops may decline by as much as 50% in the future (IPCC, 2014). The contribution of agriculture to GDP and the production of maize, sorghum and millet have been going down since the 1960s. Although several factors can be used to explain the downwards trends, the effects of reduced rainfall due to persistent droughts cannot be discounted. The trend across the provinces is that of a worsening household food security situation in all provinces across the years, consistent with the decline in rainfall over this 5-year period. The spatial distribution of food insecurity measure is also consistent with the provinces' agricultural production potential, which is underscored by rainfall and soil conditions. For example, consistently across the years, the higher potential provinces of Mashonaland East, Mashonaland and Mashonaland West (in that order) had the best food security scores, while Matabeleland North and Matabeleland South had the worst. The most commonly adopted coping strategies were: sale of household assets, reduction on non-food expenditure and borrowing money. Severe measures such as the sale of land or house were less common. The withdrawal of children from schools was rather undesirably common. The maize major deficit zone is mostly located in the southern parts of the country and the north-western parts (Hwange), a small portion in the eastern and north-eastern parts. Generally, drier areas such as Matabeleland South, Matabeleland North and Masvingo seem to suffer higher livestock mortality rates.

Humanitarian Impact

Droughts reduce availability of food exposing people to food insecurity. Vulnerability assessments show that the proportion of food insecure households is generally consistent with levels of food production (rainfall). Chronic drought areas such as Matabeleland South, Matabeleland North parts of Masvingo have higher incidences of food insecure households. Households rely on food aid from Government and NGO partners. For instance, a food insecurity map shows that this years, as the country is still in the wake of a bad season, nearly 90% of the households are categorised as facing food crisis. Mwenezi district, which faces chronic droughts, has the worst situation and categorised as "Emergency". Households resort to a number of strategies to cope with food shortages and some of these strategies such as distress sell of productive assets and withdrawal of children from school may drive them into deeper poverty. Shortage of safe drinking water during droughts presents a serious distress to communities as they walk longer distances to find water for own consumption and for their livestock.

Drought Risk Predictions

Drought forecasting is largely done by MSD. Seasonal focus is divided into two sub seasons: October to December and January to March. Sometime in August, MSD provides a forecast for the October to December season and the second forecast towards the end of December. MSD also provides daily, ten-day forecasts mostly used by farmers to plan their agricultural activities. The information is normally disseminated to the public through television broadcasts and other media channels.

Drought Monitoring
Agricultural Research and Extension Services (AGRITEX) also does drought monitoring by assessing the crops and livestock's water requirement. They mainly use the Water Requirement Satisfaction Index (WRSI) in drought monitoring. The use of remote sensing and GIS is largely the domain of scholars. Some scholars using RS and GIS were able to compute Normalised Difference Vegetation Index (NDVI); Vegetation Condition Index (VCI); Temperature Condition Index (TCI), and The Vegetation Health Index (VHI). MSD also uses Standardised Precipitation Index (SPI). Bindura University of Science and Technology, in collaboration with the Civil Protection Unit and funding from the World Bank, are in the inception phase of a project. This project will focus on the Standardised Precipitation Index (SPI) and Palmer Drought Severity Index (PDSI). The project has not started, and there is scope to work with this project.

Drought Exposure Analysis Methods include Vulnerability Annual Assessment, Lean Season Assessment and Crop and Livestock Assessment. The Vulnerability Annual Assessment is designed to assess the impact and severity of both drought on rural livelihoods. The primary data collection tools used structured household tool and the District key informant tool. The Lean Season assessment focuses on the rainfall season quality, crop and livestock condition, food and livestock markets; household income sources and livelihoods strategies; domestic and production water situation; child nutrition; food and nutrition interventions, shocks and hazards and food security. The crop and livestock assessment is done in two phases. During the first quarter of the season, the first round is to establish the area planted and growing condition for all crops and the condition of grazing for livestock. The second-round crop and livestock assessment is done during the last quarter of the season to estimate the yield and condition of livestock.

Drought forecast models
MSD is the only institution responsible for the weather forecast. It does this by bringing academia and other experts to develop weather forecasts, particularly the OND and JFP season. Although there are no other institutions providing weather forecast, we noted that there is expertise within the country to do weather forecast, but they do not have the mandate to disseminate weather information, for example, the Department of Physics at the University of Zimbabwe. Non-government organisations work in collaboration with MSD on projects that require weather forecast. The incorporation of indigenous knowledge into weather forecast has not been well developed – and this is an area where the project can work with local experts

CONCLUSIONS
Climatic conditions have been changing over time is predicted to increase. These predictions imply that the adverse effects of climate change will increase in both intensity and frequency. Climate change effects are projected to reduce staple crop yield and thereby plunge hundreds of smallholder farmers into chronic food insecurity, malnutrition, and abject poverty. The most affected districts are in the Southern parts of the country and also along the Zambezi valley, which tends to experience persistent droughts.

Climate forecasting information is mainly done by the MSD in collaboration with other scholars, and such information is disseminated to farmers through the media. The use of Indigenous knowledge, though important to the local communities in predicting drought risk, has been sidelined. At community level many households still use the Indigenous knowledge, however this knowledge system needs support to be preserved and shared more widely. The country has a comprehensive multi-stakeholder approach to monitoring the effects of climate change. There are useful drought risk monitoring methods used by academics that are not yet mainstreamed into the multi-stakeholder systems.

RECOMMENDATIONS

Although the MSD provides weather forecast regularly, Zamasiya et al., (2019) show that only 67% of farmers access such information. The remainder relies on indigenous knowledge for drought risk forecasting. We propose that the project working with climate change experts can amalgamate indigenous knowledge in drought risk forecasting.

The Department of Agricultural Research and Extension undertakes drought risk monitoring using tools such as water requirement satisfaction. However, the expertise to undertake crop water requirements satisfaction needs to be further strengthened as some extension officer did not have the expertise to do so.

While implementing this project, it is important to take note of similar initiatives and seek to establish and further strengthen beneficial collaborative relationships. For example, The Zimbabwe Red Cross Society is implementing similar projects in Matebeleland North and South Provinces and BUSE, in partnership with CPU with funding from World Bank, are also in the process of doing a similar project.

There are spatial variations of the effects of climate change. Some districts are affected more than others. Generally, drier areas such as Matabeleland South, Matabeleland North and Masvingo seem to suffer more from the effects of drought. Based on the findings of this study and the interviews with the provincial level stakeholder, we propose the following project sites.

Proposed Regions	**Recommended district**	**Drought prone classification**	**Remarks**
Matebeleland North	Tsholotsho	Mild	Already selected
	Lupane	Mild	Proposed to replace Umguza, which is classified as moderate
Matebeleland South	Beitbridge,	High severe	Proposed to replace Mangwe, which classified as moderate
	Matobo	High severe	Already selected
Masvingo	Chivi,	High severe	Already selected
	Mwenezi	High severe	Already selected

Manicalands	Buhera,	Mild to Moderate	Already selected
	Chimanimani	High severe	Already selected
Mashonaland Central	Mbire	Mild	Already selected
	Rushinga		Already selected
Mashonaland east	Mudzi	Mild	Already selected
	UMP	Mild	Already selected
Midlands	Mberengwa	Severe	Proposed to replace Gokwe South which classified and moderate
	Gokwe North	*Mild*	Already selected
Mashonaland West	Makonde	Mild	Already selected but concentrate on the old communal areas where rainfall is very poor and erratic
	Sanyati	Mild	Already selected

LIST OF ACROMYNS

AGRITEX	Agricultural Research and Extension Services
APF	Agricultural Production Form
AWS	Early Warning Systems
BUSE	Bindura University of Science Education
COMESA	Common Market for Eastern and Southern Africa
CPU	Civil Protection Unit
EMA	Environmental Management Agency
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
FBA	Forecast Based Action
FGD	Focus Group Discussion
GDP	Gross Domestic Product
GIS	Geospatial Information System
IIED	International Institute for Environment and Development
IPCC	Intergovernmental Panel on Climate Change
JFM	January February March
LULC	Land use/Land cover
MAMID	Ministry of Agriculture, Mechanization and Irrigation Development
MET	Meteorological
MLAWCRR	Ministry of Lands, Agriculture, Water, Climate and Rural Resettlement
MSD	Meteorological Service Department
NDVI	Normalised Difference Vegetation Index
NGOs	Non-Govenmental Organisations
NPP	Net Primary Production
OND	October November December
PDSI	Palmer Drought Severity Index
RS	Remote sensing
SADC	Southern African Development Community
SAFIRE	Southern Alliance for Indigenous Resources
SPI	Standardised Precipitation Index
TCI	Temperature Condition Index
UMP	Uzumba Maramba Pfungwe
UNDP	United Nations Development Programme
VCI	Vegetation Condition Index
VHI	Vegetation Health Index
WRSI	Water Requirement Satisfaction Index
WV	World Vision
ZIMSTAT	Zimbabwe National Statistics Agency
ZimVAC	Zimbabwe Vulnerability Assessment Committee
ZINWA	Zimbabwe National Water Authority

1 INTRODUCTION

Climate change is a major global environmental challenge that is adversely affecting agricultural systems, ecosystems services, water supply, and food security mostly in developing countries (Komba & Muchapondwa, 2018; IPCC, 2014). The effects of climate change can be negative or positive, and these are a function of the geo-location, institutional capacity, income levels, and level of reliance on climate-sensitive resources (Porter, et al., 2014). These effects are characterised by changes in rainfall, an increase in the number of drier seasons, and an increase in temperature (Ubisi, Mafongoya, Kolanisi, & Jiri, 2017; Debela, Mohammed, Bridle, Corkrey, & Mcneil, 2015). Some areas will become wetter, while others will become drier and warmer with extensive droughts. Changes in rainfall and temperatures will adversely affect agricultural production through altering physiological processes in crops, heat stresses, reduced water availability, declining soil fertility and increased pests and diseases (Ubisi, Mafongoya, Kolanisi, & Jiri, 2017). Effective response to climate change depends on the institutional capacity of a country to accurately forecast weather patterns both in the long run and over a season. The purpose of this report is to conduct Drought Hazard Risk and Humanitarian Impact Analysis and Inventorization of Forecast Models in Zimbabwe.

2 SCOPE OF WORK

2.1 Objective

The objective of this study is to deliver an updated and comprehensive:

(i) Analysis of drought hazard risk and humanitarian impacts and
(ii) Inventory of existing drought forecast models.
See Appendix 1 for the terms of reference

3 RESEARCH METHODS

3.1 Identification of Appropriate Research Methods

In this section, the researchers discuss appropriate research methods used to collect data necessary for addressing each of the research questions. Table 1 presents the research questions as mandated in the consultancy and the chosen methods for addressing each of the questions.

Table 1: Research Questions and research methods used

Research Questions	Key issues	Proposed methods of data mining
a) Working with the AGRITEX, MSD, Department of Civil Protection, research institutions, experts, among other actors, the consultancy should:	Changes in climatic conditions over time focusing on precipitation temperature Current methods used by government and scholars for analysing drough risk in Zimbabwe	Key informant interviews with key stakeholder which include AGRITEX, MSD, Civil Protection Unit Development partners, Research institutes

• Conduct an overview of existing drought risk analyses and methods in Zimbabwe.		
• Conduct an analysis of drought hazard risk in the country and the associated humanitarian impacts based on relevant identified indicators	Changes in agricurlal production as a result of droughts focusing on contribution of agriculture to GDP, trends in the production of major crops	Literature Review (see Table 2 Below) Key Informant Interviews with National, Provincial and District Stakeholders **Provincial and District level** AGRITEX, MSD, Civil Protection Unit Development partners - WV Research Institutes Literature Review and key informant Interviews
• Conduct an analysis of historic agricultural drought events and their respective humanitarian impacts.	Other historical records will include data on food security and household welfare collected by development partners	Secondary Sources such as reports from the Ministry of Agriculture, research articles, and Key informant Interviews with National, Provincial and District level CPU members and development partners
• Provide a prioritization of the regions based on the results of the analysis.	Which regions are facing severe droughts	Based on research findings obtained from the above-mentioned methods
• Document the results of the analysis in a report for presentation at a validation forum		
b) Provide an inventory of drought forecast models addressing the following key questions		
• Which agency produces which forecast in Zimbabwe?		Key informant interviews - MET Department - AGRITEX - Members of the CPU at the National, Provincial level A direct review and inspection of the various models issued
• What kinds of forecasts are produced, or which methods, datasets and indicators are used to produce the forecasts?		
• What is the format of issuance? Deterministic - Showing a single outcome without conveying potential error and uncertainty;		

Probabilistic -Showing the probabilities of one or more discrete outcomes or categories; Intervals- Showing an explicit upper and lower limit between which a value is expected to occur.		
• How often is the forecast produced?		
• Is the forecast generated by a computer model or produced by human estimates?		
• What is the lead time for each forecast, i.e. what is the time between forecast issuance and the shock?		
• What regions are covered by the forecast?		
• What is the benefit/skill of the forecast? How was the skill assessed (skill at a specific location, skill at predicting extreme events)?		
• What is the resolution in space or time?		

3.2 Data Collection Techniques

Table 1 has shown that to address the research questions given above, key informant interviews were used and secondary data were also solicited to establish trends in changes in key indicators as caused by climate change.

3.2.1 Literature Review

Literature review provided a detailed overview of the drought hazard risk and humanitarian impacts. The official documents such as Zimbabwe Vulnerability Assessment Committee and Meteorological Reports, First and Second round crop and livestock assessment report 2009/2010 and 2019/2020 seasons were reviewed.

3.2.2 Key informant interviews.

In order to understand the drought hazards risks and humanitarian impacts, and inventory of existing drought forecast models, key informants were interviewed. Checklist of questions is presented in Appendix 2. These were drawn from government departments, researchers and development partners that are involved in drought risks and forecasting or use drought forecasting information. A list of the respondents is presented in Appendix 3

3.2.3 Reflection and feedback

The consulting team had some reflections with the project team at different stages of the assignment. The reflection sessions were focused on the scope of the work, planning and briefing on progress, preliminary results, and final findings.

3.2.4 Minimization of risks and mitigation of potential harms

The study was conducted when people were still having the psychological effects of COVID-19 and were worried about contracting the disease. There was also danger to both the research team and the respondents as they could be infected. The country was on lockdown, and therefore the researchers could not physically visit government offices. The researchers therefore did online interviews.

4 RESEARCH RESULTS

Conduct an analysis of Drought Hazard risks in the country and associated humanitarian impact based on relevant identified indicators

4.1 Drought in Zimbabwe: An Overview

Drought can be defined in four dimensions: meteorological, hydrological, agricultural, and socioeconomic (Wilhite and Glantz, 1985).

Meteorological

Meteorological drought is defined usually on the basis of the degree of dryness (in comparison to some "normal" or average amount) and the duration of the dry period.

Hydrological

This is caused by the impact of a reduction in precipitation on natural and artificial surface and sub-surface water resources. It occurs when there is substantial deficit in surface runoff below normal conditions or when there is a depletion of groundwater supplies. Hydrological drought reduces the supply of water for irrigation, hydro-electrical power generation and other household and industrial uses.

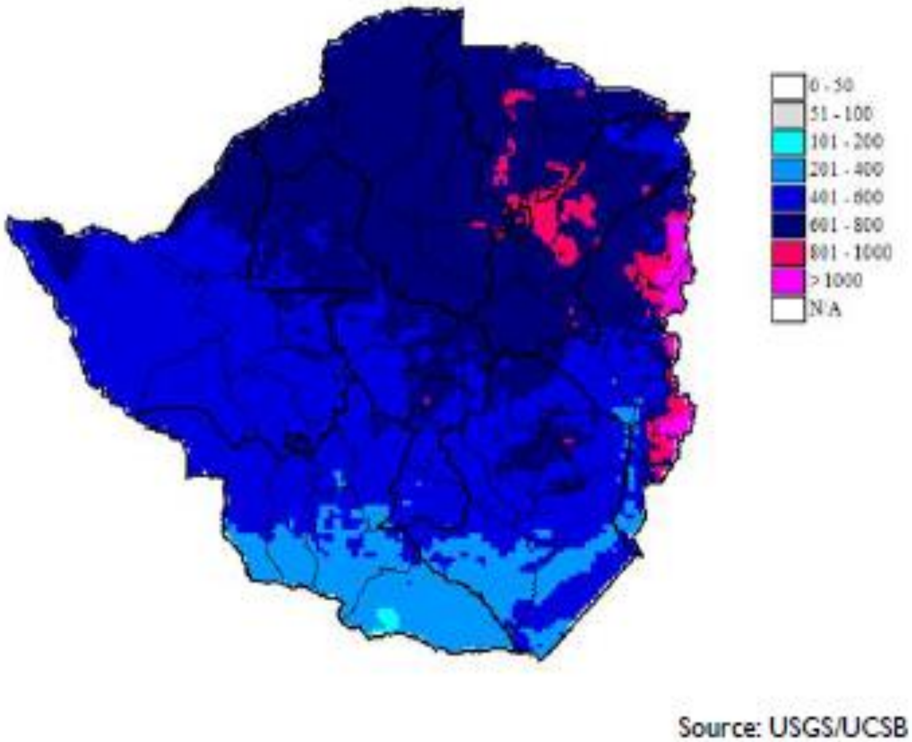
Agricultural

Agricultural drought occurs when rainfall amount and distribution over the production season is poor leading to reduced crop and livestock production. If droughts are severe, total crop failure can be experienced.

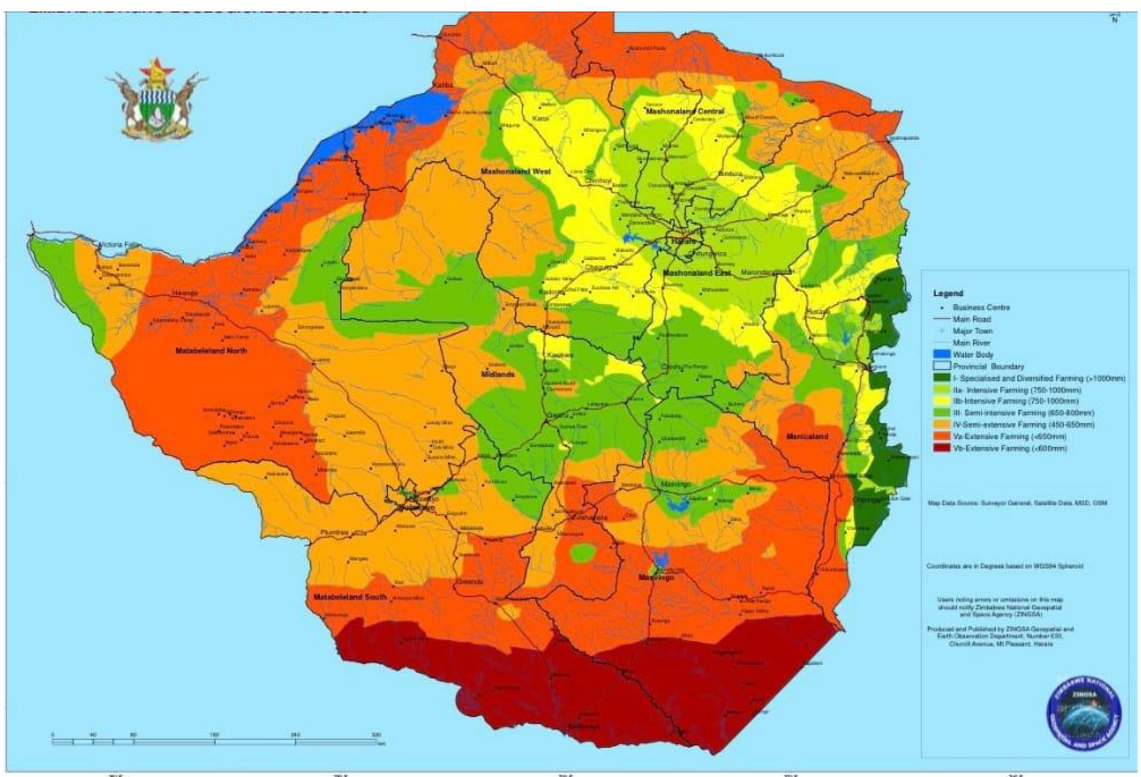
Socio-economic

This refers to the direct and indirect impacts of the earlier forms of drought on the economic and social wellbeing of people. For example, droughts can result in reduced crop yield, livestock death, scarcity of drinking water etc. This will impose socioeconomic shocks to communities as they grapple with food insecurity, reduced incomes and scarcity of safe drinking water.

There is a natural spatial variation in the moisture/precipitation as well as the severity of drought across the country as determined by the natural ecological zones.



Map 1: Map showing average annual Rainfall (1981 – 2012)



Map 2: Map showing the Agro-ecological Zones of Zimbabwe

The major determinant is the resultant crop yields or the extent of crop failure. In Zimbabwe, the staple crop is maize, and over 97% of the crop is rain-fed. Therefore, the natural rain conditions play a large part in the production of maize in the country, as is in much of southern Africa. Typically, the growing season in Zimbabwe is October-April, which coincides with the onset and termination of the rain season; also, this is when the temperatures are ideal. The quality of the growing season is determined by three factors, onset of the rains, amount, and distribution throughout the entire growing season. Late onset or early termination of rains reduces the length of the growing season, negatively affecting crop yields. Prolonged dry spells that may occur during the growing season are a typical challenge. Depending on their length and at what stage of crop growth, they occur the mid-season dry spells may have devastating effects on crop yields. Droughts also affect livestock production, particularly cattle, which is the most important livestock in Zimbabwe. The range conditions, and drinking water sources which depend on the rainfall, affect the productivity of cattle. However, crops are more sensitive to rainfall pattern than natural veldt.

Table 1 chronicles the occurrence of droughts in Zimbabwe and the southern African region starting from the 1800s. The Table indicates the occurrence of cycles of wet and dry years in the southern African region over the recorded time period. Droughts have been a part of the rainfall pattern in the history of the region. The period 1800-30 experienced historically significant droughts such as the *Madlantule* drought, which catalysed upheavals and the great migration of peoples in the southern African region (*Mfecane*) as the fight for good land intensified. Periods of excessive rainfall were also experienced. For example, 1974-80 was a wet period, with the entire southern Africa region recording above 100 percent normal rainfall.
In summary Table 1 gives an overview qualitative historical exposé of droughts in Zimbabwe and the sub-region. The learning points are perhaps that drought has been a climatic phenomenon that seems to occur in a cyclical pattern in the country and region. However, more quantitative treatment of droughts, which became possible with availability of more granular data (more weather stations and satellite data) is necessary to better describe droughts in terms of time and space. And this is done in the proceeding sections.

Table 2: History of drought occurrence in Southern Africa

Period	Rainfall situation
1800-30	Southern African rivers, swamps and other water sources dried up.
	Some well-watered plains turned to semi-arid vegetation.
1820-30	This was a decade of severe drought throughout Africa.
1844-49	Southern Africa experienced five consecutive drought years.
1870-90	This period was humid in some areas, and former Lake Ngami, in the northwest of Botswana, was full.

1875-1910	There was a marked decrease in rainfall in southern Africa, and 1910 experienced a severe drought.
1921-30	Severe droughts in the region.
1930-50	Southern Africa experienced dry periods alternating with wet ones, and in some years, the rains were very good. The 1946-47 season experienced a severe drought.
1950s	There was abnormally high rainfall in some parts of the region. East Africa experienced flooding, and Lake Victoria rose by several metres. Elsewhere, the equatorial region experienced below normal rainfall.
1967-73	This six-year period was dry across the southern African region.
	The equatorial region experienced above-average rainfall.
1974-80	This period of six years was relatively moist over much of southern Africa. In 1974, the average annual rainfall was 100 percent above normal throughout the region.
1981-82	Most of southern Africa experienced drought.
1982	Most of sub-tropical Africa experienced drought.
1983	This was a particularly bad drought year for the entire African continent.
1985	Conditions improved.
1986-87	Drought conditions returned.
1991-92	Southern Africa, excluding Namibia, experienced the worst drought in living memory.

Source, State of the environment in Southern Africa, SADC, 1994

4.2 Trends in Zimbabwe's climate variables

4.2.1 Rainfall patterns in Zimbabwe 1951 - 2008

Figure 1 depicts the annual rainfall as a percentage of the long-term normal in Zimbabwe from1951-2008. Most of the years received rainfall amounts that fall within the 125% above-normal and the 75% below-normal band (the blue lines). The period 1974-80 had the greatest amplitude of above-normal rainfall in Zimbabwe, consistent with the rest of the region as noted in Table1. The period 1981-84 experienced the worst consecutive low rainfall seasons; 1983 had the lowest dip. The period 1991-92, which was heralded as the worst drought in southern Africa in living memory, has a remarkable dip as well. It is import to point out that the total amount of rainfall aone does not give a complete picture of droughts. The distribution of rainy days in very important as we

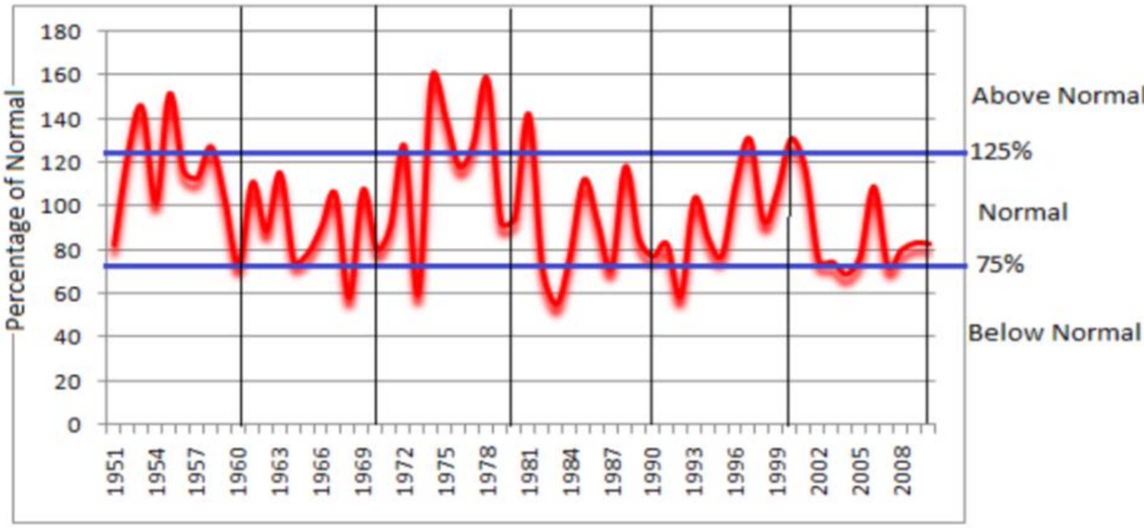


Figure 1: Time series data showing the extreme rainfall years in Zimbabwe, Source: Mangombe (2009)

4.2.2 Changes in Temperature and precipitation

The observed trends of rainfall and temperature are presented in Figure 1 below. As shown by the linear trend in Figure 1, temperature has been increasing since 1961and rainfall patterns have not been stable while exhibiting a downward trend. It is interesting to note that drought years (1970, 1982, 1992, 1995, 2002 and 2015) are described by low rainfall or negative rainfall deviations, which also corresponds to low crop yield per hectare, as shown by Figure 4 to11.

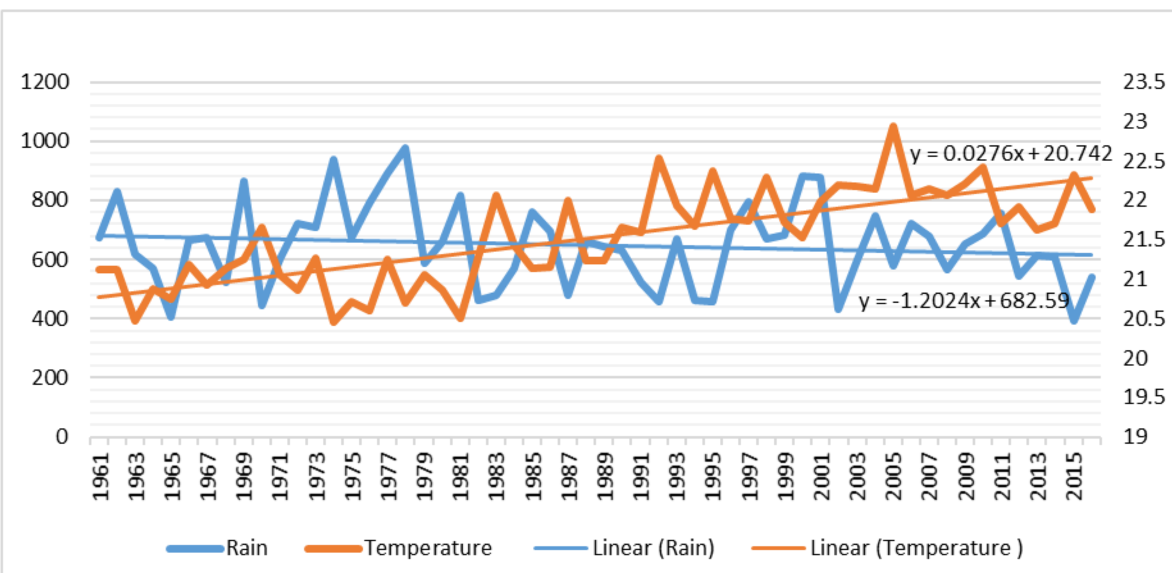


Figure 2: Temperature and Precipitation Trends in Zimbabwe

Source: Zimbabwe's Meteorological Services Department

It is also important to note that the droughts in the years 1970, 1983, 1992 and 2005 were associated with higher temperatures which had significant negative effects on crop yields. The relationships revealed by these graphs indicate that it is important to quantify the effects of climate variables on crop production.

4.2.3 Severity and spatial distribution of drought

The distribution of rainfall across the country varies largely following the natural ecological zones which are determined by geographical factors like altitude and location relative to the major rainfall systems in the country and region. Low lying areas generally receive less rainfall than areas at higher altitude. Rainfall generally decreases east-west and north-south in Zimbabwe.

GIS data based on satellite imagery show the general moisture conditions across space and time. Table 3 shows the results of a satellite-based study that captures and compares the average moisture conditions in Zimbabwe across the years: 1989-2019. The study used the Vegetative Health Index (VHI) to proxy the seasonal moisture conditions. Five categorizes based on the value of the VHI were used to indicate the severity of drought: No drought; Mild drought; Moderate drought; Severe drought; and Extreme drought.

According to this study (see imagery in Figure 3), 1991/92 was the worst drought year in both the severity and coverage. A large swathe of the country is covered under the "Extreme drought" category with very few strips under "Moderate drought". The periods 2015-16, 1994-95 and 2002-03 in that order were the other severe drought years in the country. Over this 30 year period, 1998-99 is the only rain season without a blemish of drought in the entire country. Otherwise, every other year drought of some form occurs in some parts of the country. Generally, the western and southern areas of the country seem more prone to droughts across the years.

According to the study (Frischen et al. 2020) "five districts with the most droughts events are Beitbridge (7.05 droughts in 30 years), Hwange (6.91), Bulilima (6.90), Buhera (6.84), and Tsholotsho (6.70). The five districts with the lowest average of drought events were Mutasa (1.99), Zaka (2.36), Morondera (2.69), Wedza (2.74), and Nyanga (2.89). When looking at the average number of drought events on a provincial level, Matabeleland South and Matabeleland North indicated the highest average of drought events, followed by the Midlands Province, Mashonaland West, Mashonaland Central, and Manicaland. Masvingo and Mashonaland East have the lowest average of drought events" (see Fig.4).

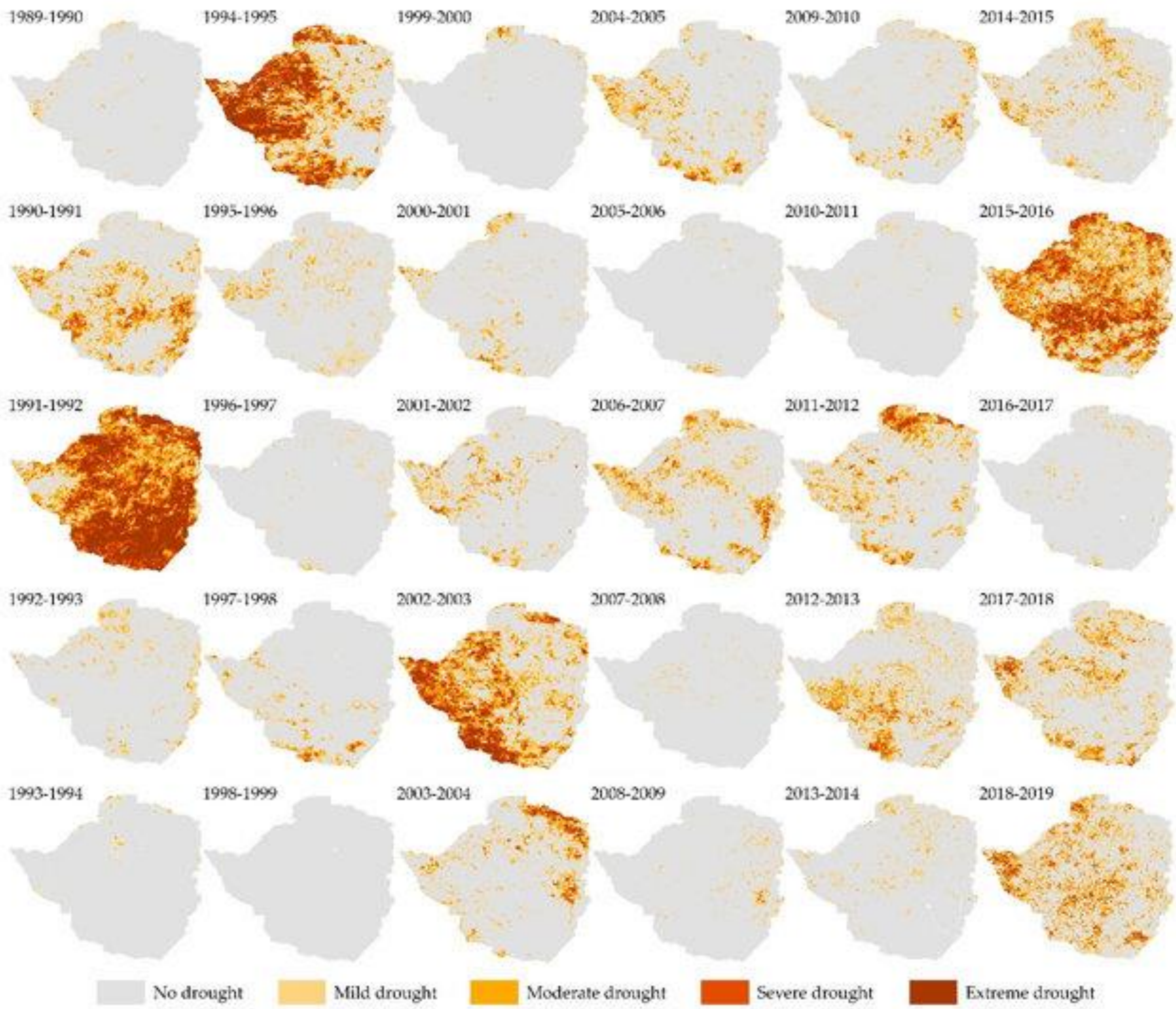


Figure 3: Seasonal Vegetation Health Index (VHI) in Zimbabwe (1989 - 2019)

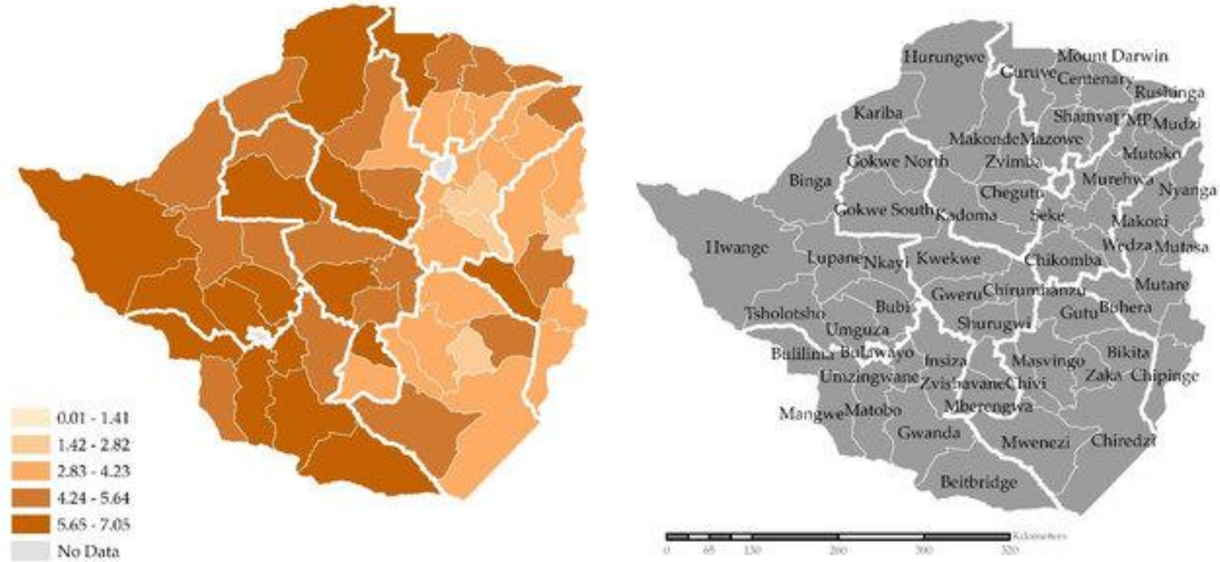


Figure 4: Average of drought years during 1989 - 2019

4.2.4 Frequency of drought in Zimbabwe

From time to time, Zimbabwe has experienced droughts. During these times, grasses and trees wilt, livestock die from hunger and thirst, and farmers experience crop failure. The history of drought can be traced back to pre-colonial times. Zimbabwe has experienced several mild, severe and extreme droughts (see table 3).

Table 3: Distribution of Droughts since 1968

Drought Classification	Extreme droughts	Severe Droughts	Mild droughts
Years	1983, 1992	1968, 1973, 1982, 2004	1951, 1960, 1964, 1965, 1970, 1984, 1987, 1991, 1995, 2002, 2003, 2005, 2007, 2008, 2009, 2010
Number	2	4	16

Based on predicted climate change scenarios, drought occurrences and durations are expected to experience increased frequencies (IPCC).

Despite the evidence of climate change, the use of seasonal climate forecasts and early warning signals to trigger pre-defined anticipatory actions is very limited in Zimbabwe. It is assumed that with access to seasonal weather forecast, smallholder farmers are likely to plan and take remedial actions prior to a drought risk in order to mitigate the anticipated impact on food security, lives and livelihoods

Table 4: Past, Current and future prediction in changes in climatic conditions

CLIMATE FEATURE	KEY MESSAGES	SOURCE
Past Climate Variability	• High variability • There have also been substantial periods, of frequent drought years and occasional flood events	Historical rainfall records
Past Climate trends (1901 to 1970)	**Temperature** • Increasing temperatures (~0.1°C/decade) **Precipitation** • Precipitation has decreased by approximately 0.6 mm/year from 1901	Historical temperature and rainfall records from MSD
Present (based on historical climate conditions and recent trends, generally over the past few decades : 1970-2020)	**Temperatures** • High veld temperatures vary from 12–13° C in winter to 24° C in summer. • Lowveld the temperatures are usually 6° C higher, and summer temperatures in the Zambezi and Limpopo valleys average between 32° and 38° C • Mean annual temperature has increased by roughly 0.01°C/year from 1901 to date • The daily minimum temperatures have risen by approximately 2.6°C over the last century while daily maximum temperatures have risen by 2°C in the last century • From daily records, it can be concluded that the frequency of cold nights and cold days has decreased by about 1.2 and 1.1% per decade respectively (that is a reduction of four (4) cold nights and 1 cold day less every ten years) from 1971-1995 • Warm day frequency has increased by about 1.9% per decade (that is about seven (7) warm days more every ten years) **Precipitation** • The timing and amount of rainfall received are becoming increasingly uncertain • There has been an overall decline of nearly 5 percent in rainfall across Zimbabwe during the 20th century, with the early 1990s witnessing probably the driest period in the past century • The last forty years (from 1980), have seen a trend towards reduced rainfall or heavy rainfall and drought occurring back to back in the same season • Eastern parts receive the highest amount of precipitation (above 1000 mm), and southern parts of the nation generally receive the least amount of precipitation (below 400mm). **Drought**: • The timing and amount of rainfall received are becoming increasingly uncertain • The last four decades have shown a trend towards reduced rainfall or heavy rainfall and drought occurring back to back in the same season.	• Zimbabwe's National Climate Change Response Strategy • Nations Encyclopaedia • Zimbabwe Meteorological Service, • IIED • Climate Change Information Fact sheet. • IPCC

	• Shifts in the onset of rains, increases in the proportion of low rainfall years, and increases in the frequency and intensity of mid-season dry-spells have been observed • The frequency and length of dry spells during the rainy season have increased while the frequency of rainy days has declined **Winds** • Tropical cyclones have increased in frequency and intensity	
Future climate (generally 2020 to 2050)	**Temperature** • Increasing temperatures of around 2.5°C by 2050 **Precipitation** • Possible decrease in rainfall particularly during the rainy season onset (Sep-Nov) • Rainfall variability and distribution to increase and climate-related hazard events, such as droughts may become more frequent **Drought** • Climate change is likely to increase disaster risks through an increase in weather and climate hazards (particularly floods and drought) • Future precipitation projections show changes in the scale of the rainfall probability distribution, indicating that extremes of both signs (floods and droughts) may become more frequent in the future • Groundwater recharge is projected to decline • Rising global temperatures will lead to an intensification of the hydrological cycle, resulting in dryer dry seasons and wetter rainy seasons, and subsequently increased risk of more extreme and frequent floods and drought	• World Climate Research Programme's • Coupled Model Inter-comparison Project Phase 3 (CMIP3) • Global Climate Model Multi-model Projections & Climate Systems Analysis Group(CSAG), • IPCC

source: https://www.nationsencyclopedia.com/Africa/Zimbabwe-CLIMATE.html#ixzz6mjJfclKV

4.3 Impacts of Drought: An Overview

Table 5 presents some projected impacts of climate change on agriculture, water, foretry and biodiversity and rangeland in Zimbabwe based on the research work of Brown, et al. (2012).

Table 5: Projected Impact of Climate Change on Selected Sectors

Sector	Projected climate change impact
Agriculture	▪ The general vulnerability of communal agriculture to climate change and variability ▪ Generally, maize suitable areas will decrease by 2080, while cotton and sorghum suitable areas will increase by 2080 ▪ Generally, there will be an increase in severe droughts by 2050 ▪ In the Southwestern parts of the country, Sorghum and maize will become increasingly vulnerable to climate change, while cotton will become less vulnerable ▪ In the north-central and eastern parts of the country, maize, Sorghum, and cotton will become less vulnerable
Water	▪ Overall, surface water resources are projected to be reduced significantly by 2080, irrespective of the scenario used

	▪ Northeastern and the eastern parts of Zimbabwe are predicted to experience a surplus in surface water, while the western and southern parts of Zimbabwe are projected to experience a drying up ▪ Runoff will decrease significantly in the Umzingwane, Shashe, Nata, and Save catchments ▪ Groundwater recharge will change at a rate directly proportional to change in precipitation ▪ The northern part of Zimbabwe will be the least affected by climate change and most affected in the dry southern catchments of Mzingwane and Runde by 2080
Forestry and biodiversity	▪ Expected minimum pressure on plant diversity for best- and worst-case scenarios is 42%
Rangelands	▪ Net Primary Production (NPP) will decrease from the current average maximum of over 8 tonnes per hectare per year to just over 5 tonnes per hectare per year by 2080 ▪ This translates to decreased rangeland carrying capacity for both livestock and wildlife ▪ Southwest and north-western parts of Zimbabwe will experience more reductions in NPP than in other parts of the country

4.3.1 Trends in agriculture production

About 70% of the population of Zimbabwe resides in communal areas and directly dependent on agriculture for food and income as smallholder farmers. Predominantly the agriculture practised is rain-fed. Maize is the staple crop, with tobacco, and groundnuts as the common cash crops. Some irrigated horticulture production is done on small parcels of land along riverine and wetlands, where water is available. These small gardens are usually relied upon for the supply of vegetables for their own consumption and cash income. Smallholder farmers also keep livestock, mostly cattle (they account for the largest proportion of the national herd), goats and poultry. The livestock production systems are mostly extensive; largely dependent on the natural veld for feed and water. Farmers' livelihoods are intertwined with rainfall; a poor rainfall season usually spells hunger and livelihood loss for most of the country's population.

The economy of Zimbabwe is centred on agriculture which forms backward and forward linkages with the other sectors. For example, it provides raw materials (maize, cotton, sugarcane, tobacco etc.) used in the manufacturing sector. It provides a huge market for manufactured products (soap, cooking oil, sugar, tea etc.). Agriculture earns the country a sizeable amount of foreign currency through exports from tobacco, cotton, and horticulture. In fact, Zimbabwe's GDP growth pattern across the years closely mirrors the rainfall received in the country (see Figure 5), showing a strong linkage to agriculture.

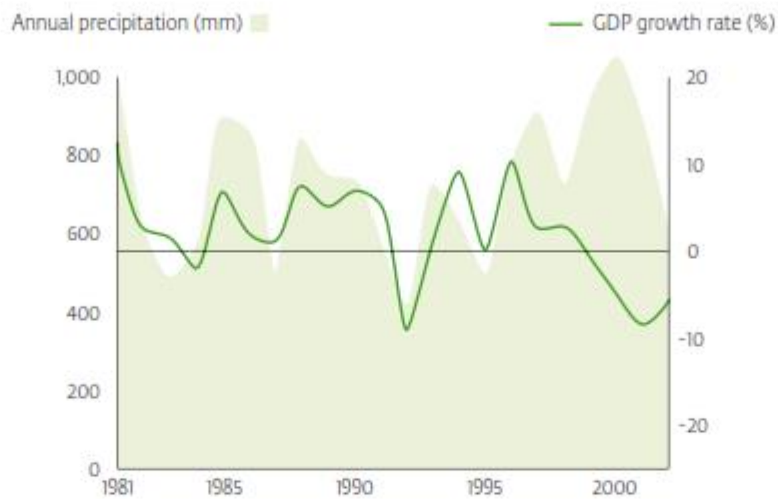


Figure 5: Correlation between GDP and Rainfall in ZImbabwe 1979 – 1993 (Brazier, 2015)

The sector has contributed about 11-22% towards the Gross Domestic Product (GDP) for the past two decades (see Figure 2). Since the sector provides livelihoods to approximately two-thirds of the country's population, its performance is critical for rural livelihood and poverty reduction. Figure 6 below shows that contribution of agriculture towards the GDP has been fluctuating and declining. Although the decline could be attributed to many factors such as reduced soil fertility as a result of floods, lower technology adoption and investment thresholds, shortage of finance and power, poor institutional and physical infrastructure, the high frequency of drought occurrence resulting in low and variable precipitation cannot be discounted. Drought is recorded as the most common natural hazards occurring in Zimbabwe between 1982 and 2011, accounting for six out of ten top major natural disasters (EMA/UNDP, undated)

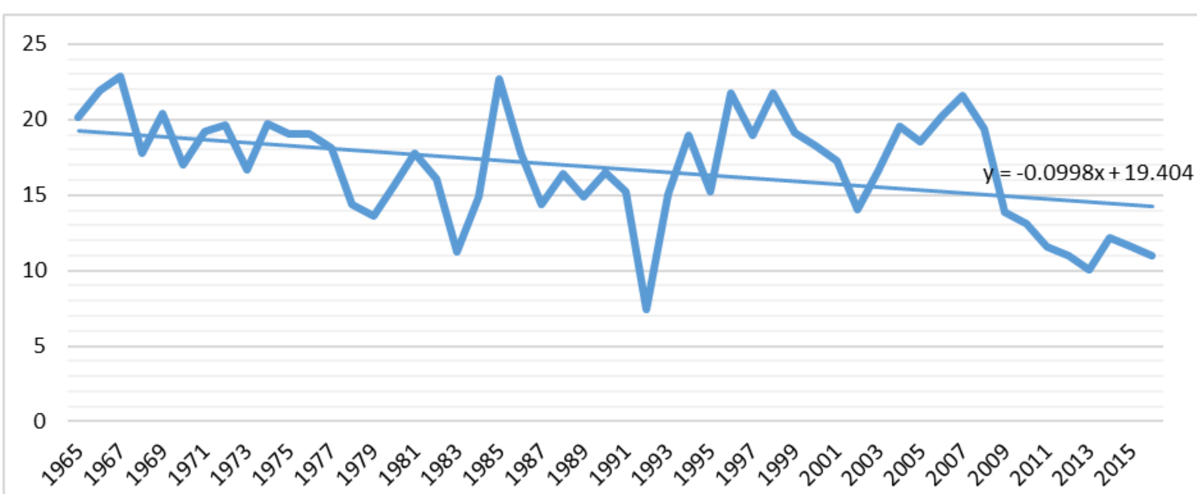


Figure 6: Agriculture value added (%GDP), Source: World Development Indicators, 2019

Figure 7 shows agriculture, crops, cereals and food production indices. The trends show that production has been on the downward trend since the 1973 drought. The trends in production indices reveal that productivity in agriculture was highly sensitive to climate variability, particularly drought; for instance, the drought years 1992, 1995 and 2002 are associated with sharp declines in agriculture, crops, cereals and food production indices.

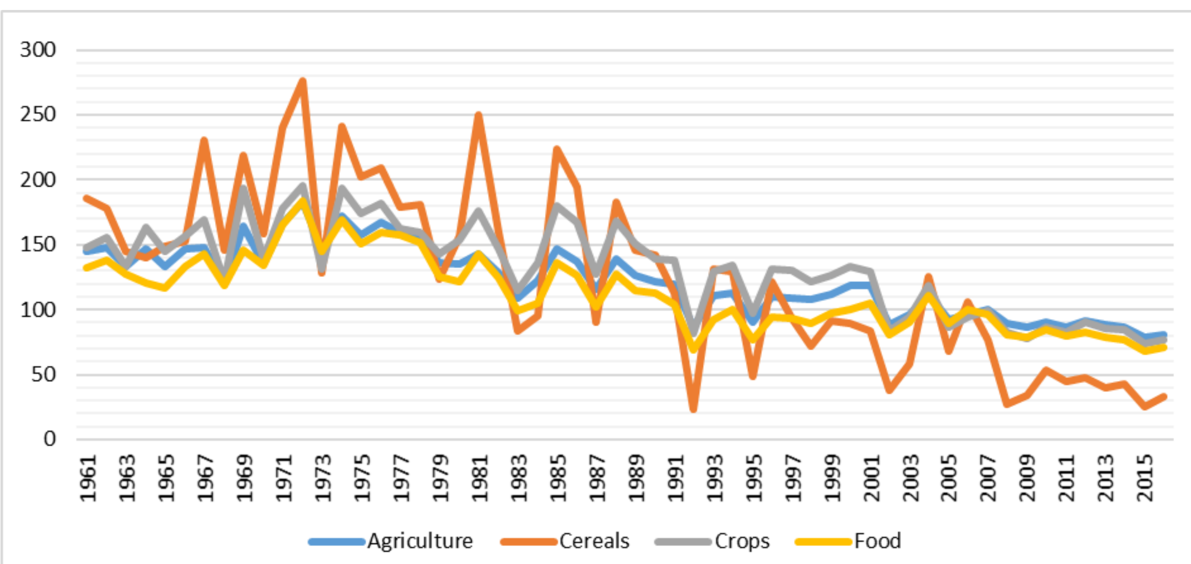


Figure 7: Agriculture, Crops, Cereals and Food Production Indices, *Source: FAO Stats,* 2019

4.3.2 Impact of droughts on Crop production

In agriculture, crop production is probably the most vulnerable and sensitive to rainfall and therefore suffers the most from droughts. In Zimbabwe, a very good crop for tracing the effect of rainfall on production is maize. This is largely because it is the staple crop, it has a relatively constant driving force for production—largely food, and less sensitive to other incentives/disincentives, unlike cash crops such as tobacco which can take swings according to prices.

Figure 8 depicts the average yields of maize obtained in Zimbabwe for the period 1961-2019. Clearly, the maize yield fluctuations mirror the rainfall fluctuations. Maize yields, similar to rainfall, make big dips in the drought years of 1982-83; 1991-92 and 2014-15. A structural decline in yields can be noted across this time period. This could be attributable to rainfall which, also exhibits a similar trend over time. This should, however, not preclude other known factors such as a decline in soil fertility, decline in the use of productive inputs such as fertilizer and manure. Economic difficulties, particularly starting in the year 2000, do contribute to the reduced use of purchased inputs such as fertilizers and high yielding seed varieties—national statistics data and other studies confirm this. The reduced use of manure could be a ramification of droughts through loss of livestock.

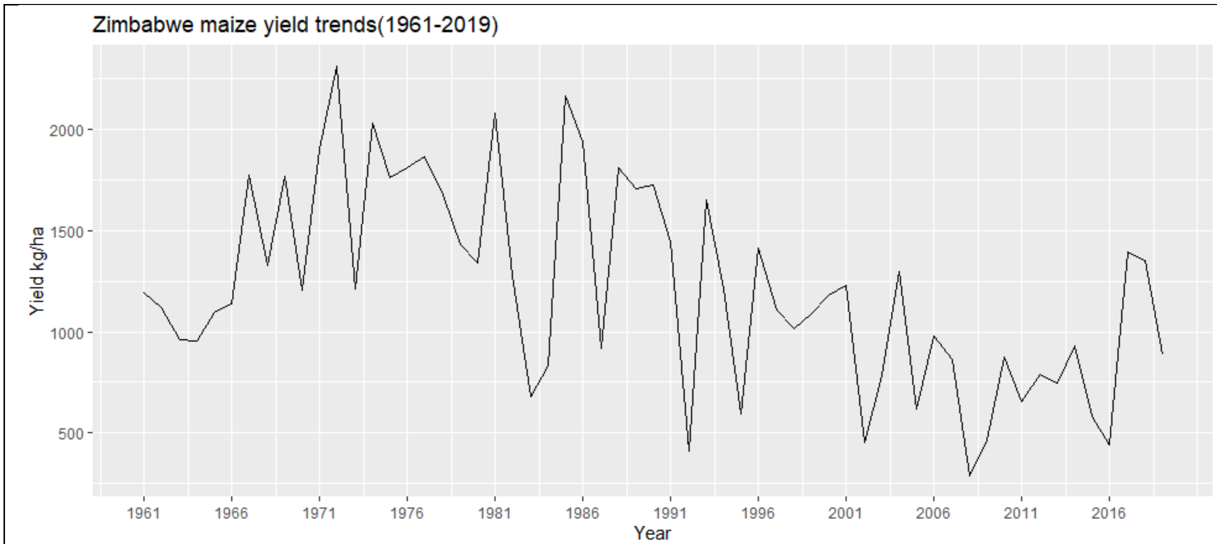


Figure 8: Changes in Maize productivity (1961 – 2019), Source: Computed from FAOSTAT data, 2021

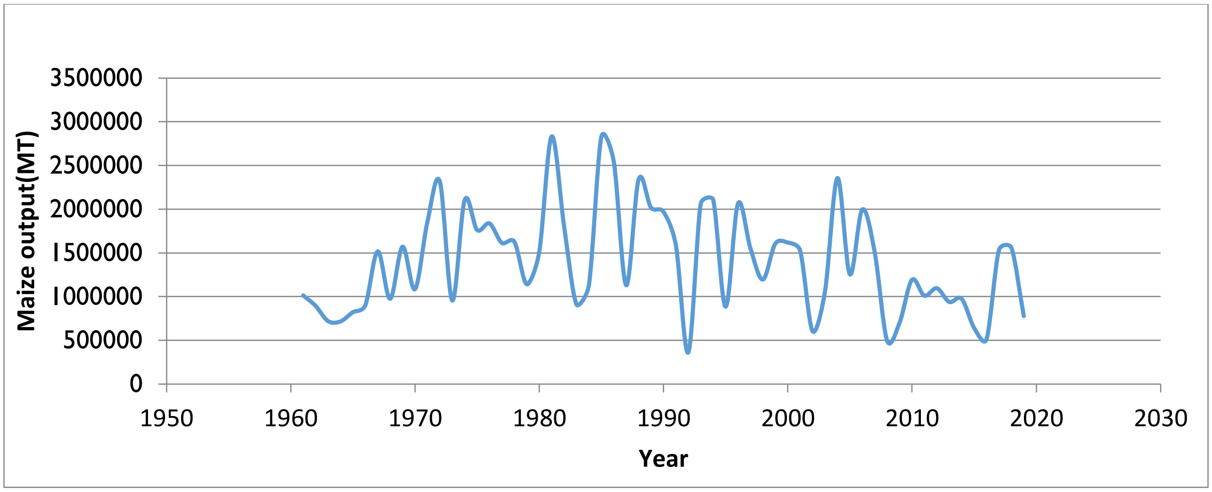


Figure 9: Changes in maize output (1961 - 2019), *Source: Computed from FAOSTAT data, 2021*

A similar pattern is observed for other agricultural crops (see Figure 9), as has been found by other studies (e.g. Mashura, in Nyikahadzoi and Mukamuri, 2021). The trends of the selected crops show that production of Sugarcane (Plate 1), Soybeans (Plate 2), Wheat (Plate 3), Sorghum (Plate 4), Millet (Plate 5) and cotton (Plate 6) have been exhibiting the downward trend for the period under study. The decline in the production of maize as a staple diet for the country poses a serious threat to national food security and health status. The decline in the production of cash crops such as cotton and tobacco also limits the development process as the nation loses foreign currency.

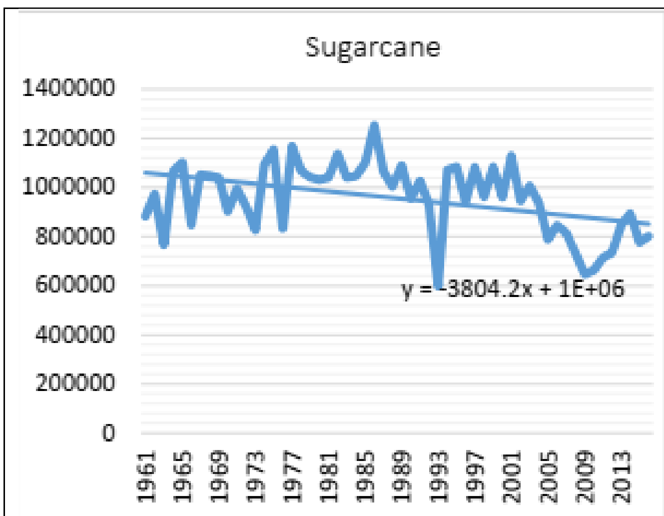


Plate 1: Distribution of Sugarcane production tons/ha

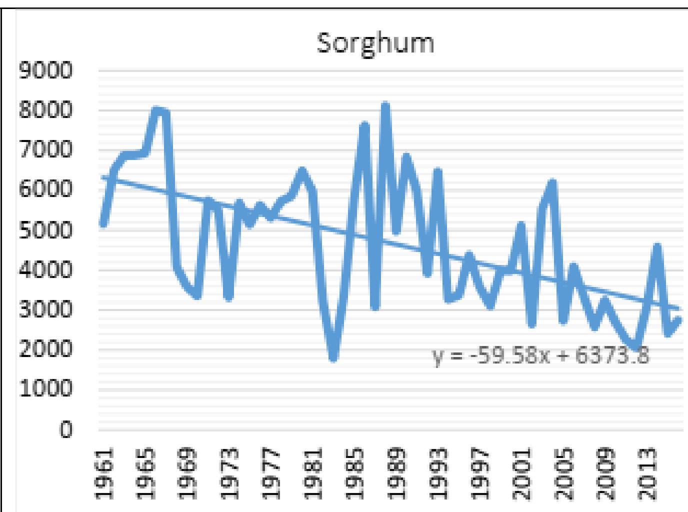


Plate 4: Distribution of Sorghum production tons/ha

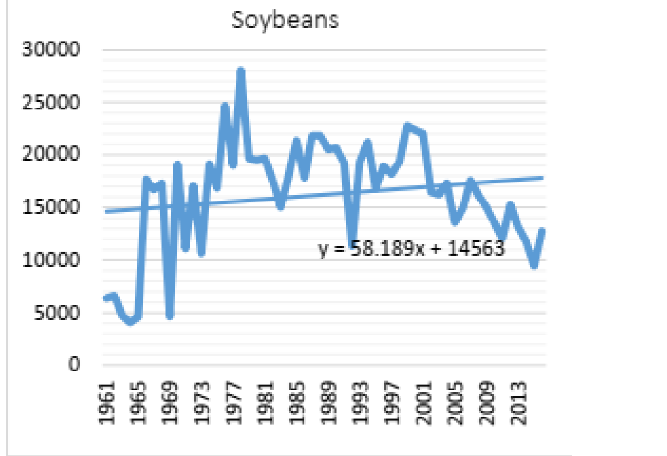


Plate 2: Distribution of soybean production tons/ha

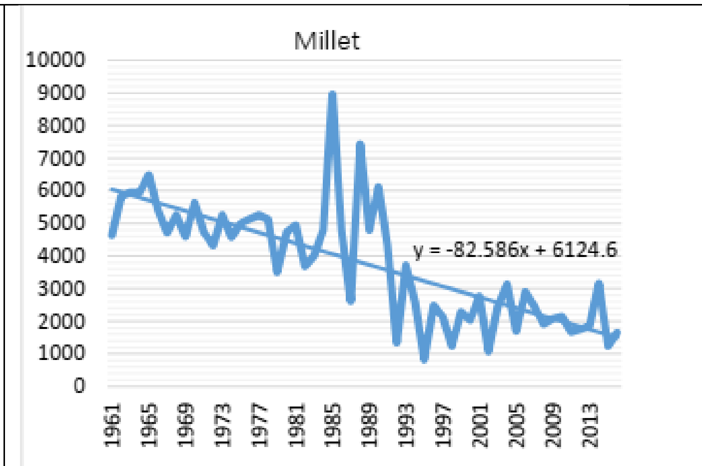


Plate 5: Distribution of Millet production tons/ha

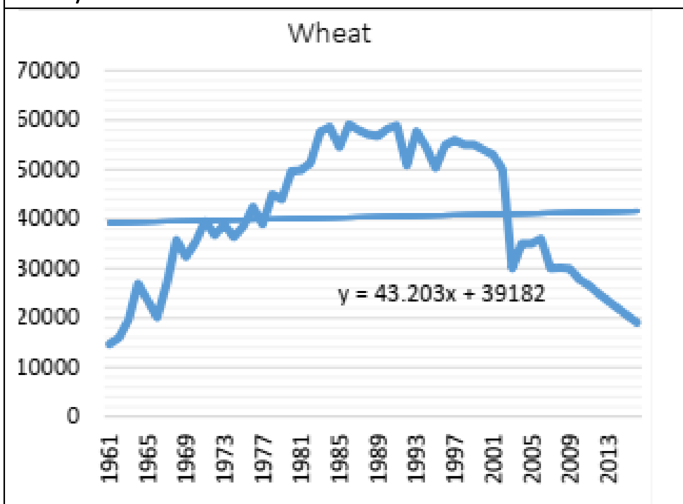


Plate 3: Distribution of Wheat production tons/ha

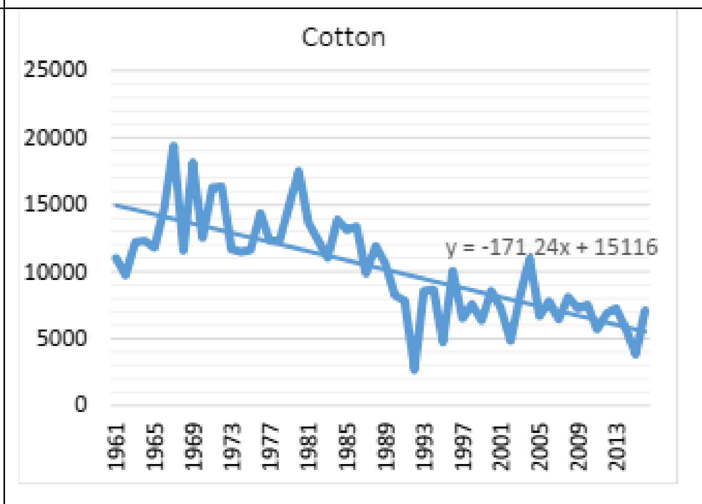


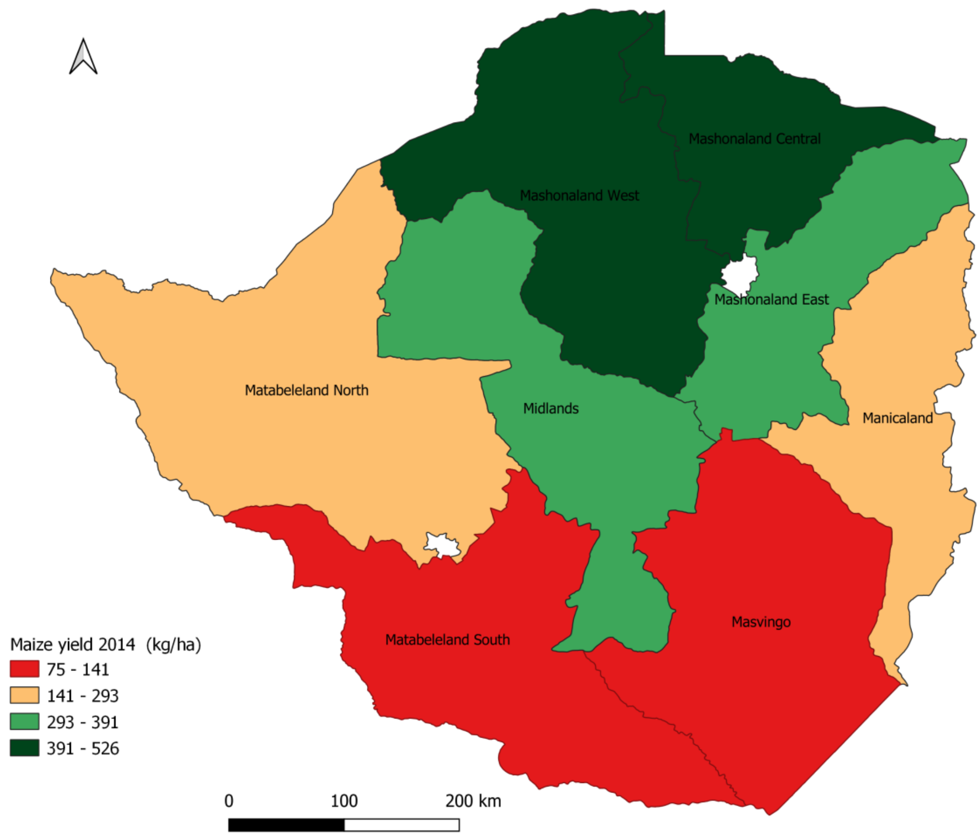
Plate 6: Distribution of Cotton production tons/ha

Figure 10: Changes in production of other crops over time

Further analysis of the trends indicates that all crops were affected by extreme events like drought. The 1992 drought experienced in Zimbabwe affected the production of all crops, as can be observed from the trends shown in Figure 10 (plates 1 – 6). It is evident from the trends that extreme events of climate change have affected crop production in Zimbabwe. The 1995, 2002 and 2005 droughts also caused a decline in almost all crops. The fluctuations in crop production followed the occurrence of drought or cyclone. For instance, the decline between 2014 and 2015 is partly attributed to El-Nino, which Zimbabwe experienced that year.

4.3.3 Spatial maize yield distribution

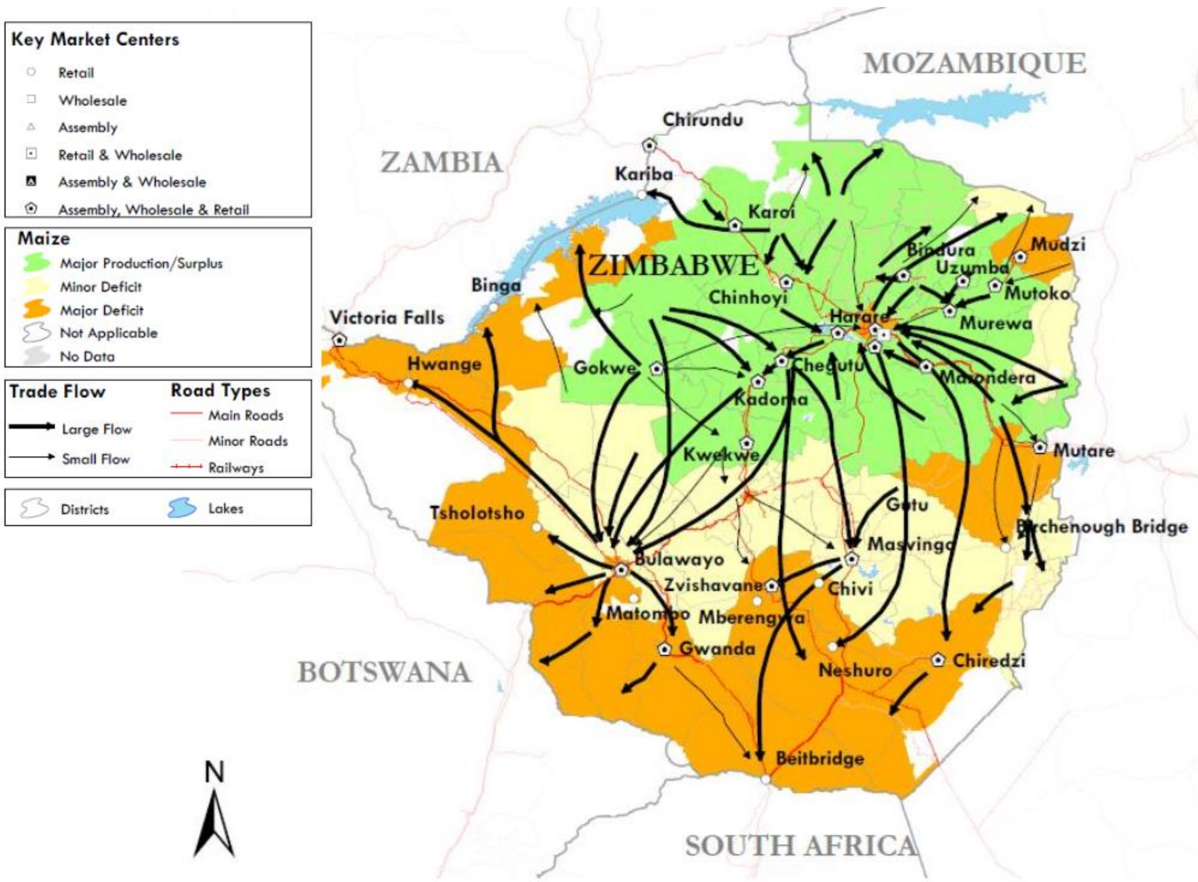
Map 3 shows the maize yields by the province during the severe drought of 2014-15. The map reinforces the previously noted pattern of increased severity of north-south and east-west. Most of the country obtained very low yields relative to the recent national average of 1000kg/ha.



Map 3: Maize yields by province in Zimbabwe 2014 – 15, Source: Computed using ZimVAC yields data

4.3.4 Impact on food security

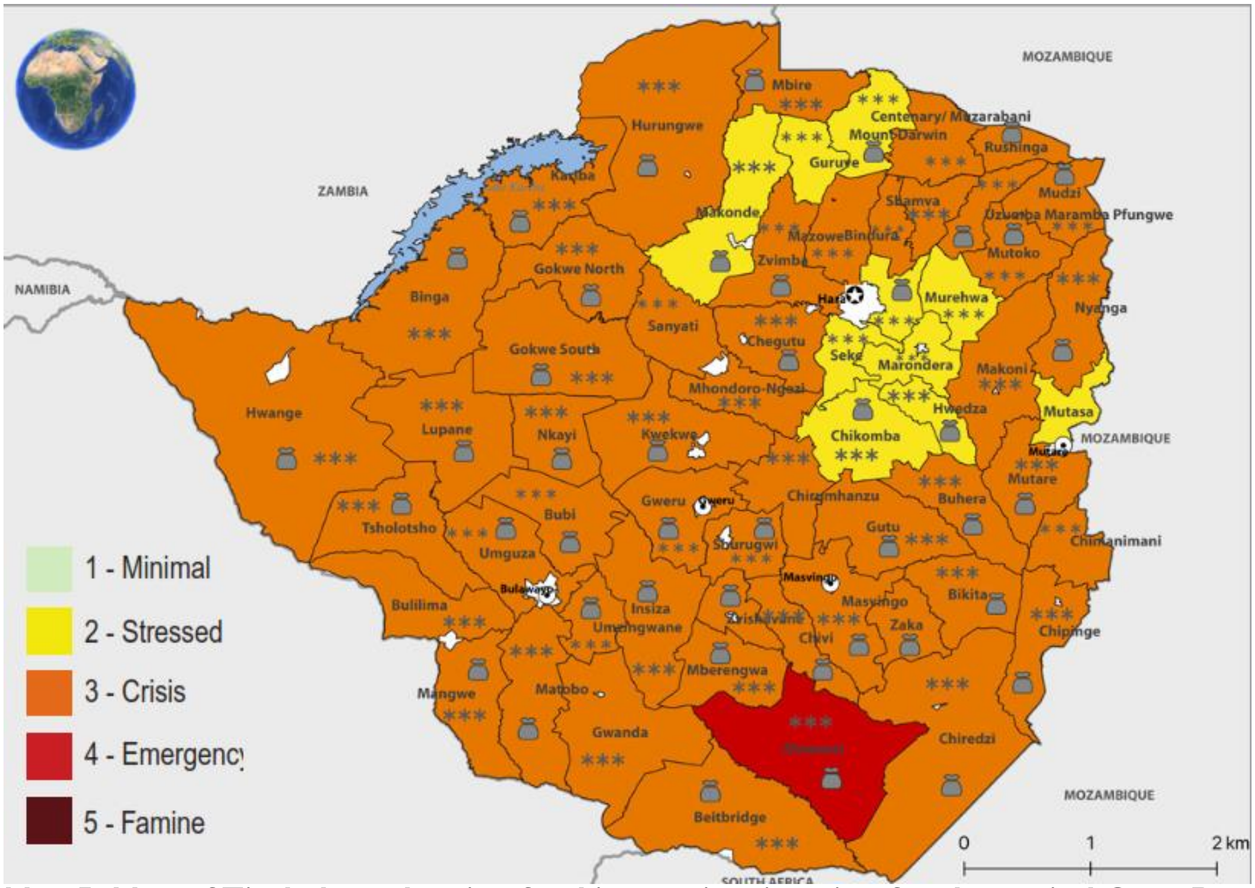
Droughts introduce a shock in the availability of crop outputs, affecting food availability at both the household and national level. Over the past two decades, the country has experienced reduced maize production and has to rely on imports from neighbours to meet the national deficit. In fact, since 2000, the country has hardly produced over 2.1 million MT of maize grain, which is the estimated national requirement to meet both consumption and industrial demand). This long-term decrease in maize production has contributed to the current maize structural deficit. Maize deficits impact market prices which generally spike in response to scarcity. The poor households, particularly those in the drier areas that experience more severe and more frequent droughts, are hit hardest as availability from own production is reduced, and their low-income status constrains their ability to purchase at the higher prices. A poverty map of Zimbabwe, confirms that poverty is more widespread and severe in the poorer agro-ecological zones (ZimStat, 2012). Households resort to harsh strategies to cope with the impact of food shortages. Generally, malnutrition rates are higher in the chronic food deficit zones of the country. Map 4 shows the market network flow of maize from high production zones to the deficit zones. Consistent with earlier discussions, the maize drain surplus zone is located in the northern half of the country, mostly three provinces, Mashonaland West, Mashonaland Central and Mashonaland East, and some small part of the Midlands. The maize major deficit zone is mostly located in the southern parts of the country (Mwenezi Beitbridget districts) and the north-western parts (Hwange), a small portion in the eastern and north-eastern parts. The remainder of the country, mostly the mid-section, is the minor deficit zone (Map 4)



Map 4 Maize Production and Market FLow Map, Zimbabwe Source: FEWS NET

Current food insecurity situation in the country

Map 4 shows an analysis of the food insecurity situation across districts in Zimbabwe for the period October-December 2020 as produced by IPC. The severity of the insecurity is scaled into 5 categories (minimal, stressed, crisis, emergence, famine), in that order. According to the IPC, currently, 2.61 million people (27% of the analysed population) in rural Zimbabwe are facing high levels of acute food insecurity. Most of the country is facing level 3(crisis) of food insecurity. This is largely because the country is in the wake of a very poor rainfall season of 2019/20. Mwenezi is the hardest hit district with level 4 (emergency) food insecurity. A few districts, in the wetter zones are better-off, level 2(stressed) namely: Makonde, Guruve, Centenary, Mt Darwin (these are part of maize belt); Chikomba, Marondera,Hwedza, Seke and Murehwa.



Map 5: Map of Zimbabwe showing food insecurity situation for the period Oct - Dec 2020

Food relief situation

Since the advent of the drought situation, the government of Zimbabwe has been distributing maize grain and maize meal as part of relief to food insecure households. In all the target districts (see Table 6) all key informants confirmed presence of food relief programme by the Social Welfare department of the GoZ. In addition to the government, NGOs are also providing food aid to the vulnerable households in the districts. Some of the NGOs mentioned include Oxfam, and Caritas.

Maize grain distribution by GoZ and Partners

According to the The Food Deficit Mitigation Programme update report of March 2021 "A total of 5,891.57 of maize grain as well as 97.55mt of sorghum and 659.90mt of mealie meal were distributed across the eight rural provinces. The combined distribution for the week therefore stood at 6,551.47mt. The quantity of grain moved during the week brought the cumulative total distributions since January 2021 to 30,788.26mt." Table 6 shows the breakdown of the distribution of the maize grain for the period by provinces.

Table 6: Showing weekly distribution of relief by province as at 23 March 2021

National	Number of Households	Grain required p.m.	Weekly Distribution	Monthly Distribution	Cumulative Distribution
Manicaland	83,997	4,199.85	363.45	1,481.30	3,139.41
Mash Central	70,080	3,504.00	305.00	2,111.00	3,139.00
Mash East	65,627	3,281.35	587.25	1,643.05	2,981.55
Mash West	84,552	4,227.60	856.55	1,676.49	2,458.03
Masvingo	134,719	6,735.95	1,402.96	3,335.61	5,926.05
Mat North	51,810	2,590.50	315.70	1,332.20	2,159.91
Mat South	68,380	3,419.00	628.15	1,952.42	3,075.05
Midlands	176,290	8,814.50	1,432.51	3,367.11	7,909.26
Total	735,455	36,773	5,891.57	16,899.18	30,788.26

Source: THE FOOD DEFICIT MITIGATION PROGRAMME, 21 March 2021 update report

4.3.4.1 Food security at the household level

Starting 2014, the annual national survey has been undertaken to track the vulnerability of households to droughts under the auspices of the Zimbabwe Vulnerability Assessment Committee (ZimVAC.). A number of indicators of household livelihoods and welfare, including household food security, are measured.

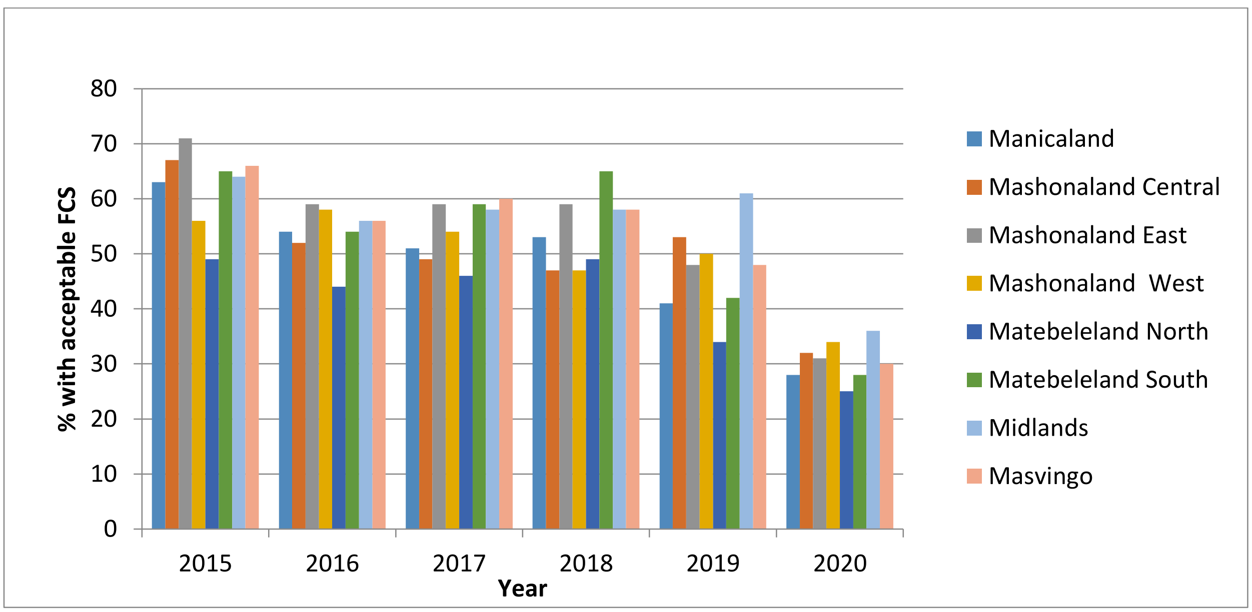


Figure 11: Distribution of households with acceptable food consumption score by province

Figure 12 depicts the household food security status in the country's provinces from 2015-2020 obtained from ZimVac reports. Data predating years prior to 2014 is not available as ZimVac only started in 2014; regrettably, this data prior to 2014 is therefore not available. The trend across the provinces is that of a worsening household food security situation in all provinces across the years, consistent with the decline in rainfall over this 5-year period. The spatial distribution of food insecurity measure is also consistent with the agricultural production potential of the provinces, which is underscored by rainfall and soil conditions. For example, consistently across the years, the higher potential provinces of Mashonaland East, Mashonaland and Mashonaland West (in that order) had the best food security scores, while Matabeleland North and Matabeleland South had the worst.

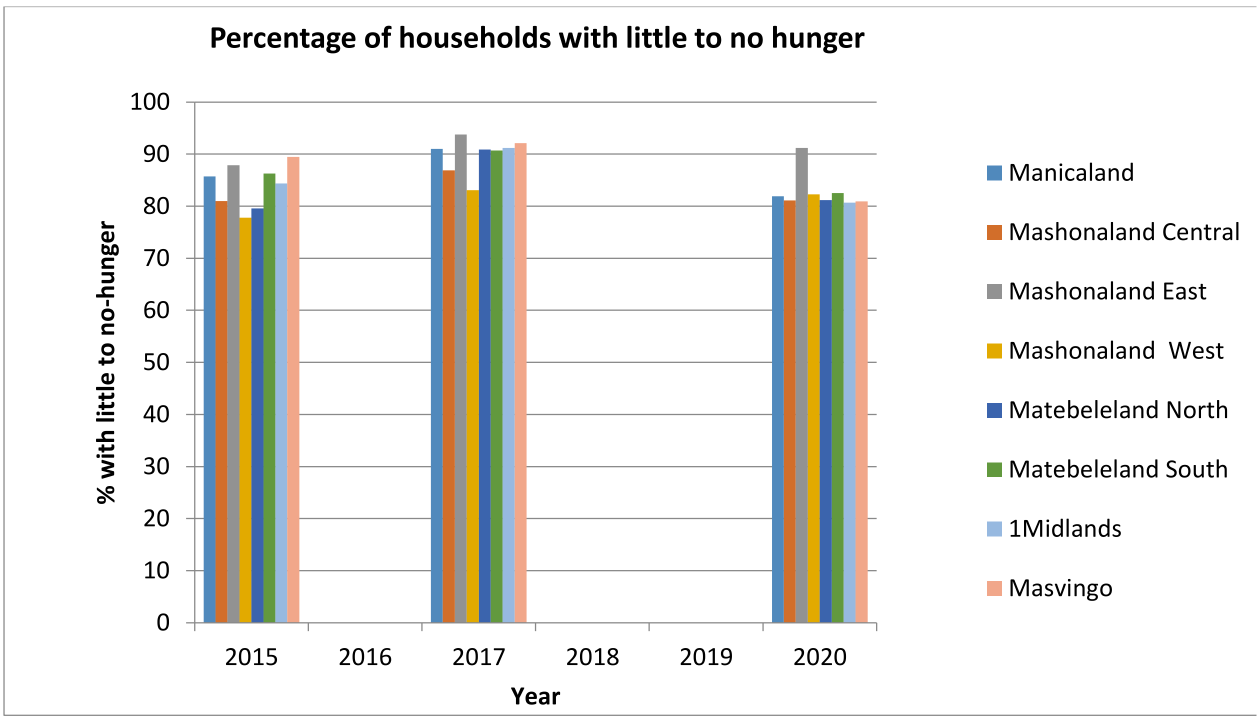


Figure 12: Distribution of Households with Little to no Hunger by Province, *Source: computed from ZimVac data*

Figure 14. Status of household food security by province 2015-2020

Household coping strategies

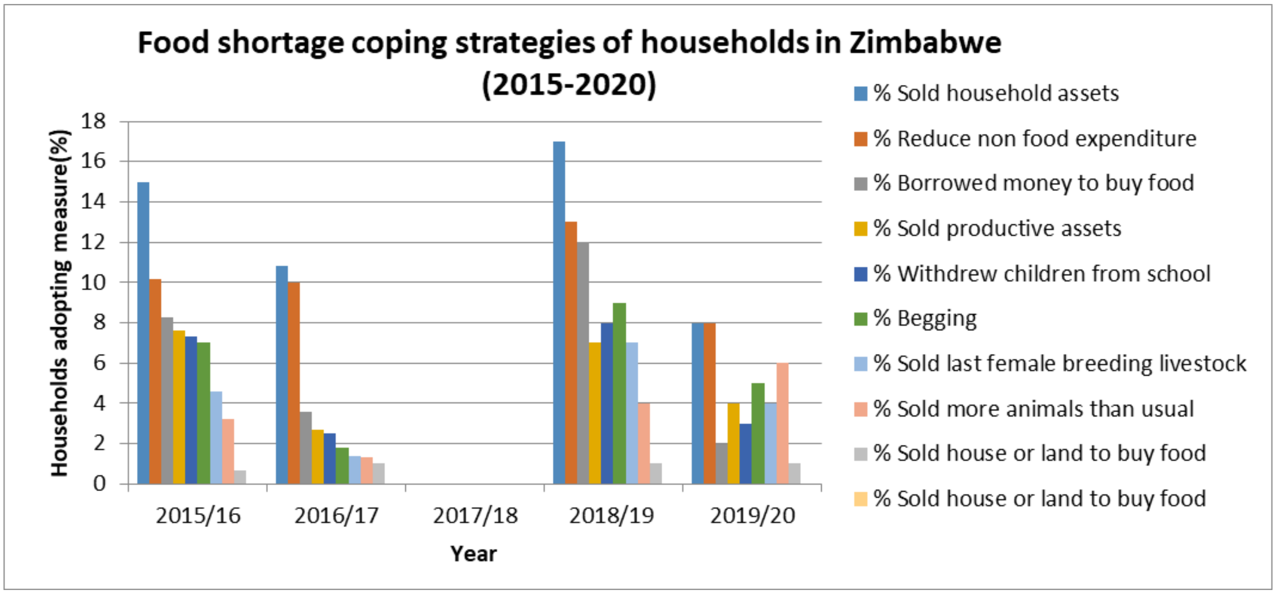


Figure 13: Food shortage coping strategies of household over time in Zimbabwe 2015 – 2020, Source: computed from ZimVac data

Faced with food shortages, households are pressed to resort to some strategy to cope with this shock. Some of the coping strategies, such as distress sale of productive assets, entrench households deeper into the poverty cycle. Figure 14 summarises the coping strategies households resorted to for the time period 2015-2020. The most commonly adopted coping strategies were: sale of household assets, reduction on non-food expenditure and borrowing money. Severe measures such as sale of land or house were less common. The withdrawal of children from schools was rather undesirably common.

4.3.5 Impact on Livestock Production

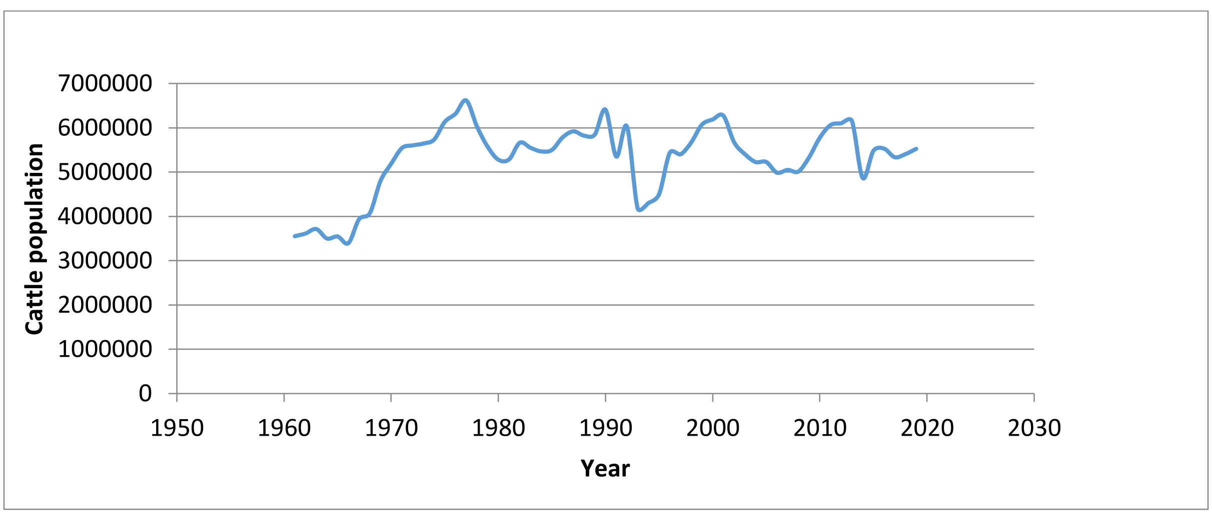


Figure 14: Changes in National herd size 1961 - 2019

Droughts also impact livestock production through the quality and availability of graze, cost and accessibly of crops based feeds, drinking water quality and availability and occurrence of diseases and animal conditions associated with dry weather such as high temperatures. Severe droughts are commonly marked by the death of livestock, particularly cattle. The trend in cattle population is generally steady, and less responsive to rainfall amount than crop production. However, severe droughts have had a huge impact on the cattle population, as seen for the years 1982 and 1992—extreme drought years that saw the death of many cattle (Fig.15). Figure 16 shows the livestock mortality rates by provinces in Zimbabwe for the period 2014-2020. The mortality rates generally are correlated to rainfall pattern. For instance, the highest mortality rates across all provinces for this time period are observed in 2014-15, which was a drought year throughout most of the country. Generally, drier areas such as Matabeleland South, Matabeleland North and Masvingo seem to suffer higher mortality rates. The only notable exception is the unexpectedly high livestock mortality rates observed for Mashonaland East, a relatively wet zone (Fig.16). This may reflect the interplay of other factors that influence livestock mortality, such as diseases (Foot and mouth, blackleg, lumpy skin and botulism), stocking rates etc.

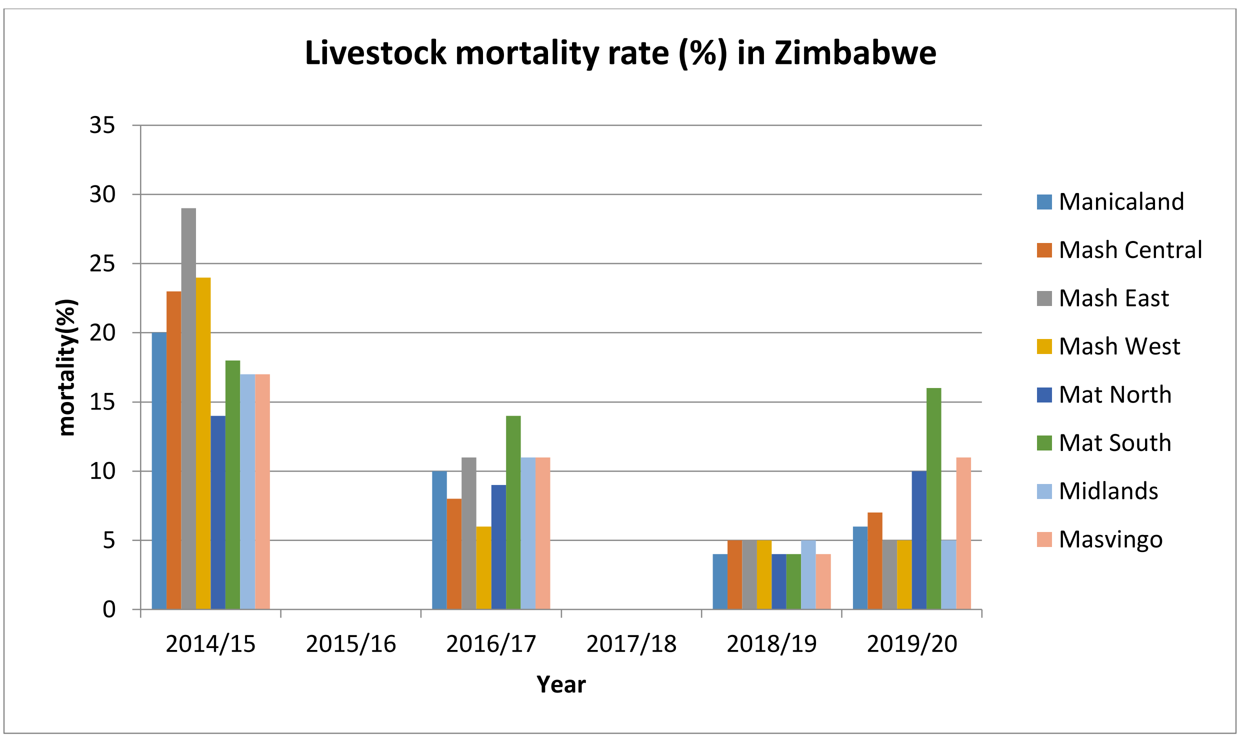


Figure 15: Livestock mortality rates in Zimbabwe by province 2014 – 2020, Source: computed from ZimVAC data

Case Study 1: Drought Experience From Manicaland Province

Mrs Shiri is a 67-year-old widowed farmer who lives in Mutanda Ward of Mutare district, Manicaland province. She lives with her daughter, three grandchildren. Her married son, whose homestead is located close by, occasionally helps her with some farm work.

According to Mrs Shiri, the worst drought in the area was experienced in 1992. The rains were so poor and sporadic that maize and all other field crops wilted and completely failed. Watermelons were the only exception; they survived the drought and were the only crop available for food that year. There was no maize meal for sadza. Her family and many others in the area cooked raw bananas, and cabbages—which they bought from irrigation farmers around Mutare City—for meals. Some days they went with no meals as they could not afford to buy enough supplies. A lot of people, particularly children, became visibly emaciated.

Water sources dried up and people had to travel to Mukunu River to fetch water. The water could only be found in a few places along the river bed. People had to queue for water and competed with animals which also drank from the same sources. The water was very muddy and dirty. Some people, especially children fell sick with diarrhoea because of the dirty water. A lot of cattle died due to starvation and lack of water. Mrs Shiri had a herd of 10 beasts, and she lost 2. Goats also died though in lesser numbers; out of nineteen goats, she lost 3. People in the area had to cut down *Mukamba* (Pod Mahogany/*Afzelia Quanzensis*) tree branches so cattle could feed on the leaves.

4.3.6 Impacts of droughts on water availability and water resources

During a drought year, a lot of water sources used by households for drinking water such as wells, springs, even boreholes may run dry and force households to travel longer distances to a few sources that may still have water such as dams or boreholes. Figure 17 indicates an association between drought occurrence and increased travel distance to a water source for households in Zimbabwe. The years 2016 and 2020 were relatively dry, and correspondingly for the same years, more households had to travel a distance of more than a kilometre to access water. In addition, more households in the drier provinces travel long distances to fetch water than in the wetter provinces. A good comparison is between Mashonaland East (wet) and Matabeleland South (dry), were 15% Vs 33% of the households, respectively, travelled more than 1 km to access water in 2016.

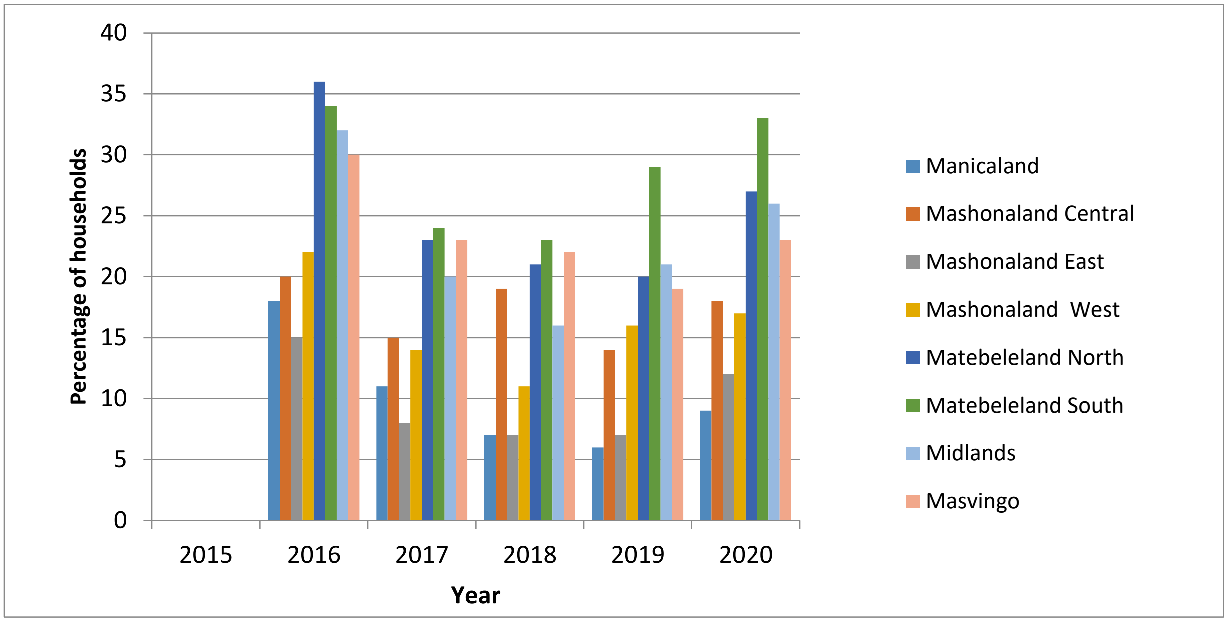
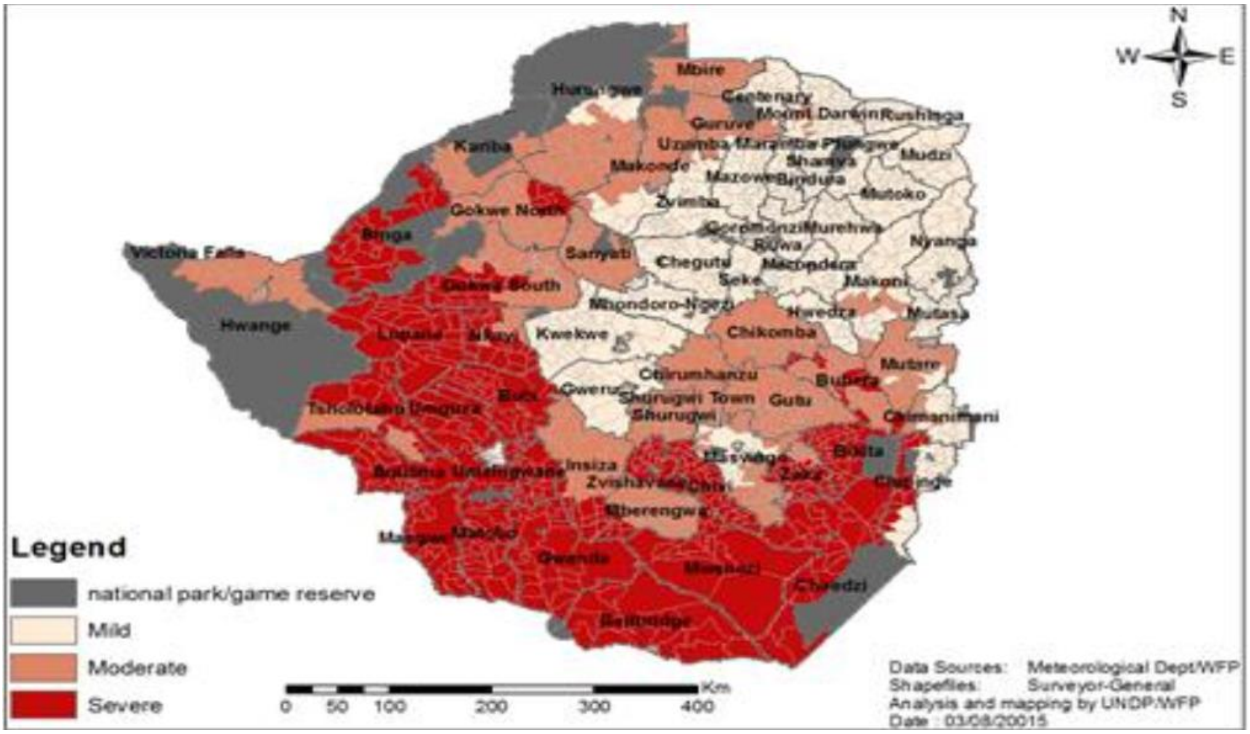


Figure 16: Percentage of households travelling more that I kilometre round trip to the nearest water source 2015 - 2020

Case Study 2: Drought Experiences from Midlands Province

Mr Shoko, aged 74, lives in Mataruse Ward of Mberengwa district in Midlands province. He recalls the 1981-82 season as the worst drought in living memory in his area. According to him, it did not rain at all, not even a drop for the entire duration of the season. Since the cessation of rains of the previous season in February 1981 through to the end of 1982 no rains fell at all. The drought had a profound impact on people, livestock and wildlife in terms of food and water supply. Since there were no rains, people could not plant maize and other crops. Maize ran out in the area. In the peak of the drought government arranged for a food relief programme through provision of subsidised maize meal that was supplied by National Foods and Blue Ribbon companies. These two companies also supplied livestock feed. People had to wait and sleep in long queues to buy maize meal. Households resorted to eating *Mauyu* (Baobab/*Adansonia digitata*) and other wild fruits such as *Shumha* (Jackalberry/ *Diospyros mespiliformis*), as they could not get enough maize meal supplies on a daily basis. People and livestock drank dirty water from few points along the river. The river Ngezi, dried up and for the first time people saw exposed basins of perennial pools/*madziva* never seen before. A lot of fish died or were caught by communities as the water dried exposing them. Other wildlife also died; Mr Shoko recalls seeing a lot of dead tortoises. Cattle died in large numbers. According to him, up to now people have not recovered their herd sizes. He for example had 57 cattle and most died except 5. Dead cattle carcasses could be seen rotting everywhere, particularly along the dry river beds. Because of starvation cattle that year developed a condition of weak leg joints. Once they stumbled and fell they would not be able to get up without the help of farmers. Farmers had to cut down branches of *Mubvumbi* tree to feed their livestock.



Map 6: Map of Drought Geographic Distribution

4.3.7 Impacts of Drought in Project Districts

Key stakeholder from the districts were asked the following questions.

1. What are the three top crops grown in the district? Rank them.
2. What are the top three livestock kept in the district? Rank them
3. Tell us more about droughts that have been happening in your district?
4. When did the district last faced a severe drought?
5. What is the estimated percent of households that were food insecure as a results of the drought (harvest did not last 12 months)? What were the copying mechanisms?
6. What is the estimated percent of cattle that died as a result of the drought?
7. Who supported the community with food?
8. How does this community predict drought or how do you foresee that there will be drought in the coming year?
9. Who is most affected by drought and why?

The results are presented in Table 7.

Table 7: The Impacts of Drought in Project Districts

Province	District	Drought prone classification	Main agricultural Activities	Most recent drought	Food Insecurity % of HH	Livestock Poverty death (%)	Drought relief Activities
Matabeleland North	Tsholotsho	*Mild*	*Crops* Small grains mostly Pearl Millet *Livestock* cattle and goats, poultry	2019-2020 The district has experienced drought in the past three season	80-88%	~5%	Government drought relief Programme WFP lean season Programme *Coping strategies* distress sell of livestock
	Umguza	*Medium*	*Crops* Most small grains (mostly sorghum) Wheat is done in 5 irrigation schemes with a total capacity of about 150 ha *Livestock* Cattle and goats, poultry	2019-2020 The district has experienced drought in the past three season	70%	18%	Government drought relief Programme WFP lean season Programme *Coping strategies* distress sell of livestock
	Lupane (suggested)	*Mild*	*Crops* *Mostly small*	The district has been experiencing perennial drought for the past 10 years	80%	25%	Government drought relief Programme *Coping strategies* Selling livestock

Matabeleland south	Matobo	*High Severe*	*Crops,* Maize, sorghum, millet *Livestock* Cattle, goats, sheep	2019-2020 The district has experienced drought in the past three season	60%	40%	Government drought relief Programme WFP lean season Programme *Coping strategies* Gold panning, Petty trading, distress sell of livestock Remittances(cash and groceries) from South Africa
	Mangwe	*Medium*	*Crops* Maize, sorghum, pearl millet, cowpeas, groundnuts, Bambara nuts *Livestock* Cattle, goats, sheep, donkey, poultry	2019-2020 The district has experienced drought in the past three season	60%	30%	GoZ, Social Welfare NGOs -Caritas (supporting 3 wards) -Oxfam *Coping strategies* Distress sell of livestock and assets Remittances(cash and groceries) from Botswana South and Africa
	Beit bridge (suggested)	*High Severe*	*Crops* Sorghum, Miller, water melons *Livestock* Cattle, donkeys, goats	The district has been experiencing severe drought over the past 10 years	80 – 90%	20	Government drought relief Programme WFP lean season Programme *Coping strategies* Seek casual work in RSA
Midlands	Gokwe North	*Mild*	*Crops* Maize, cotton, ground nuts *Livestock* Cattle and goats	2017-2018	60-90%	~30% This is exacerbated by lack of drinking water as the district has very few water bodies(dams) developed.	Government drought relief Programme (Social Welfare) *Coping strategies* -On-farm income generating activities like Brick moulding -Youth move out to mining districts like Kwekwe

	Gokwe south	Mild	*Crops* Maize, cotton, ground nuts *Livestock* Cattle and goats	2017-2018	60-70%	~20% NGOs supporting access to livestock feeds	Government drought relief Programme (Social Welfare) *Coping strategies* -On-farm income generating activities like Brick moulding -Youth move out to mining areas like Kwekwe, Inyathi
	Mberengwa	Severe	*Crops* Maize, Sorghum, millet *Livestock* Cattle, goats and donkeys	Prennial droughts	80 – 90%	35 – 40%	Government drought relief Programme (Social Welfare) *Coping startegies* Young people migrating to South Africa, gold panning
Masvingo	Chivi	*Medium*	*Crops* maize, Sorghum, oilseeds, groundnuts, round nuts *livestock* goats, cattle, donkeys.	Perennial droughts, though severe in 2007-2008 farming season.	86%.	12%	Government drought relief Programme (Social Welfare) *Coping strategies* illegal gold panning, fishing, poaching
	Mwenezi	*High Severe*	*Crops* Sorghum, millet, and maize. *Livestock* Cattle, goats,	The District has been experiencing drought in the last ten years, and the most recent devastating drought happened in 2015	80%	35 – 40%	Government drought leaf Programme (Social Welfare) *Coping strategies* Cash and food remittances from their children mainly in South Africa and the diaspora, gold planning, selling of livestock,
Manicaland	Chimanimani	*High Severe*	*Crops* Maize, Sorghum and bananas, *Livestock* cattle, sheep and goats,				

	Buhera	*Medium*	*Crops* Maize, rapoko and groundnuts *Livestock* cattle, goats and road runners chicken	Perennial droughts for the past 10 years, with the 2012-2013 drought being the most recent severe drought in 10 years	80%	30%	Government drought relief Programme (Social Welfare)
Mashonaland East	Mudzi	Mild	Mixed farming and the major crops are maize, Sorghum and groundnuts, and major livestock include cattle, goats and indigenous chickens.	The district experience drought every year due to a prolonged mid-season dry spell. Groundnuts is one of the crops which does well in the District	70-80%	~45%	Government drought relief Programme (Social Welfare)
Mashonaland East	UMP	Mild	*Crops* maize, groundnuts and Sorghum *livestock* cattle, pigs and poultry	Experiencing drought over the last ten years caused by a prolonged mid-season dry spell.	50%	45%	Government drought relief Programme (Social Welfare) *Coping strategies* joining illegal gold panning,
Mashonaland central	Mbire	Mild	*Crops* Sorghum, maize and finger millet, *Livestock* Cattle, goats and chicken.	For the past ten years, the District has been experiencing droughts with the exception of this year	75%	50%	Government drought relief Programme (Social Welfare)
Mashonaland central	Rushinga	Mild	*Crops* maize, small grains such as Sorghum, and groundnuts *Livestock* goats, sheep and cattle.	Perennial droughts for the past ten years due to prolonged mid-season dry spells.	80%	10%	Government drought relief Programme (Social Welfare) *Coping strategies* selling cattle, engage in illegal gold panning, migration.

Mashonaland West	Makonde	Mild	*Crops* Maize, tobacco, soya beans and *Livestock* cattle and goats		60%	45%	Government drought relief Programme (Social Welfare) *Coping strategies* other people look for casual jobs.
	Sanyati	Mild	Crops Cotton, maize and small grains *Livestock* Cattle goats		59%	40%	Government drought relief Programme (Social Welfare) *Coping strategies*

Case Study 3: Farmer's response to drought in Beitbridge Districts

Smallholder farmer response to droughts in Beitbridge District (*Source Mr A. Mbedzi*)

Crop adaptation

The last 3 seasons have been a complete disaster as farmers got nothing to eat nor for storage. In some wards it only rained/drizzled once the whole season in 2016 and twice in 2018. Even the veggies permanently wilted as most of the boreholes also dried up. Farmers relied on vegetables imported from neighbouring districts.

Livestock

Those with resources bought commercial stock feed, some relocated their livestock to other places as far as Gwanda, Chiredzi and even Botswana and South Africa. Animals were moved to places that had better graze and water sources within and out of the district. The majority of the farmers however, watched helplessly as the animals died. Cash from livestock sales was close to zero as the prices plummeted.

Farmers could not sell their stock due to too low prizes and poor livestock condition. Boreholes were drying and only Zhovhe Dam remained with water. Farmers had no mitigation plans, A few benefited from the donor stock feed handout programs of NGOs such as International Rescue Comity, Caritas and others. Livestock were just randomly moving from red zone to free zones with little veterinary monitoring.

Copping with food shortages

Communities in Beitbridge rely mainly on groceries illegally imported/smuggled from south Africa either through the border or illegal crossing points along the Limpopo river. Some also get some remittances from their relatives working in South Africa. They also rely on food aid and cash vouchers, mainly from government and Non-Governmental Organizations (NGOs). A lot of people also do savings clubs (groceries and cash).

Case Study 4: A widow from Buhera narrating her experience during drought

My name is Mrs Mareya form Ward 30. My husband died in 2005 leaving me with four children (2 girls and 2 boys) one who was in secondary school and the other in three in Primary School. Upon his death we had 2 cattle, 5 goats and few chickens. Before his death my husband would send money and groceries on quarterly basis from Mutare where he worked as general hand at a local store. I would also farm on our little plot which would help supplement household food needs. Even during the most severe drought years as with year 2002 we would always find ways to manage the situation. When my husband passed away our life changed. I started finding it difficult to sustain my family including providing adequate food. My eldest daughter had to drop out of school as I could not raise enough income. Now she is married in nearby village. My situation also becomes worse during severe drought years as I find it difficult to single handedly manage household food needs due to poor harvests. I remember when a severe drought struck this area in 2007/2008. Everyone did not have any meaningful harvest. I had relied on making porridge from *Mauyu (*Baobab/*Adansonia digitata*) to feed my family. My children would provide casual labor in nearby irrigation schemes in return for grain or food pack. I was also forced to sell one of the cattle I had so as to secure grains. Unfortunately, I did not get much as it was already wasted due to hunger. In fact, the remaining one died of starvation. From then my life has never got better and gets worse during severe drought periods. The past three years (2018, 2019, and 2020) have been hard hit by drought and I have had to depend on government food for work programs to supplement household grain. My children also harvesting and sell *Mauyu (*Baobab/*Adansonia digitata*) to outsiders at wholesale prices as means of securing income to supplement household food needs. From time to time I also sell the few chickens and goats I have to get us going. However, the monies are not much and we have had to resort to one meal a day until a time when NGO food distributions start. Still as a female head there is no guarantee you get access to it (food aid) especially if you have no one to represent your household during registration period. Surely it has never been an easy road for some female heads as myself. It's always a struggle and always wish for a better tomorrow which seems to never come.

4.4 Drought Risk Forecasting and Monitoring Methods

Working with the AGRITEX, MSD, Department of Civil Protection, research institutions, experts among other actors, the consultancy should:

A. Conduct an overview of existing drought risk analyses and methods in Zimbabwe.

Drought monitoring in Zimbabwe is carried out by two main ministries, the Ministry of Environment, Water and Climate through the Meteorological Services Department (MSD) and the Ministry of Agriculture through Agriculture Research and Extension Services (AGRITEX). The roles and responsibilities of the two organisations include systematic observation and monitoring of hydro-meteorological parameters; provision and publication of information, forecasts, products and services related to weather and climate. Also, these departments are responsible for the supply of data related to drought-relevant parameters, indices and indicators.

4.4.1 Drought Risk Predictions

The Meteorological Services Department provides early warnings to the people about drought from the time it starts disseminating the seasonal forecast. The seasonal forecast is generated by southern Africa regional climate experts together through the regional forum called the Southern Africa Regional Climate Outlook Forum and disseminated in August prior to the rainfall season. Each member state then downscales the regional forecast to their national-level, taking into account factors that influence national climate variability. Using statistical analysis, other climate prediction schemes, and experts' interpretation, climate change expert predict the rainfall outlook, which ranges from normal to below normal. Seasonal forecast is divided into two sub seasons, that is, October to December and January to March.

General characterisation of a season

- Normal – long term average rainfall received in an area
- Normal to below normal – cumulative rainfall totals most likely to be within the long term average range with a chance of going below this range
- Normal to above normal – cumulative rainfall totals most likely to be within the long term average range with a chance of going above this range

- Above normal - cumulative rainfall totals most likely to be above the long term average range with a chance of falling within the long term average range
- Below normal - cumulative rainfall totals most likely to be below the long term average range with a chance of falling within the long term average range

The MSD uses the Standardised Precipitation Index, which qualifies the severity of droughts in drought monitoring. Once the agricultural season has started, the Meteorological Office produces several reports on the season performance. The reports include daily, ten-day forecasts which are mostly used by farmers, and daily prepared shorter-range forecasts that are disseminated to the public through television broadcasts and other media channels.

A High-Performance Computer Centre was established in 2014 at the University of Zimbabwe to support research. The MSD is using high-performance computers to run numerical weather models used for weather forecasting. It was pointed out that since the MSD started using the Centre, the accuracy of weather forecasts issued by the department has improved.

4.4.2 The Use of Indigenous Knowledge

Plant-based indicators

- The abundance of Mopane pods than leaves indicates a good rainfall season.
- The appearance of the first green leaves on Mopane is a sign of planting season starts.
- The presence of sweet sugary deposits on Mopane leaves indicates high rainfall expected.
- Abundance of the wild fruit *Makwakwa* (spiny monkey orange/*Strychnos spinosa* Lam.) and other fruits like mangoes (*Mangifera indica*) symbolizes a poor season.
- Sprouting and flowering of such tree species, indicates season onset.
- Good fruiting of Amarula (*Sclerocarya birrea*) is a sign of a good rainfall season.
- The closing of spiders' nests indicates the onset of the rainy season.

Animal-based indicators

- A high caterpillar population indicates a good rainfall season.
- Cries and singing of certain birds communicate season status. When the *Haya* (Rain Cuckoo) bird cries more frequently, especially in the morning, then rains are near, and people should make ready draught power and seed.
- The sound of the *Dendera*(Hornbill) bird singing in the morning often culminates in rain cloud development and eventual rains in the later day.
- The *Nhengure* (Fork-Tailed Drongo) bird has a cry that mimics the words "wake up and go to the fields". When this sound is heard, farmers know its time to start tilling the landing preparation for the planting season.

- The presence of the *Zvikovera* (Quails/) birds on the fields indicates that the rains are going to be good, and a good crop will be harvested.
- The appearance of larger birds often signified an impending drought.
- An eagle flying high and giving a crying sound is an indication that the rains are about to come.
- The initial emergence of flying ants *Ishwa* corresponds with the start of the rainy season.
- The absence of frogs and toads indicates a dry season.
- Black ants and termites carrying food indicate a heavy rainfall or drought, depending on the community.

Other Traditional Indicators

- Excessively high temperatures around the normally expected dates for the onset of rainfall season often indicate a high likelihood of a rainfall event.
- A higher proportion of boys than girls born in a year indicates poor rainfall season.
- When a ring forms around the moon at night, it symbolises a good rainfall season ahead. This ring is called *"dziva remvura"* (halo). When this is not observed often a dry season is experienced.
- The movement of winds gives an indication of the likelihood of rainfall events. When a certain consistent wind direction is achieved, chances are higher. On the contrary, when the prevailing wind direction is not clear, then the likelihood is lower or delayed rainfall.

Source: EMA/UNDP, 2008

4.4.3 Drought Monitoring Methods

The Meteorological Service Department (MSD) monitors weather and climate-related risks and shares information with various stakeholders. MSD oversees a network of 50 synoptic weather stations that transmit data every 30 hours, sending information to collecting centres using global telecommunication systems. Out of these, 32 are automatic weather stations (AWS).

Agricultural Research and Extension Services (AGRITEX), a department within the Ministry of Lands, Agriculture, Water, Climate and Rural Resettlement (MLAWCRR), also does drought monitoring by going further into getting the water requirement for the crops and livestock through the use of temperature, soil quality, evapotranspiration and rainfall. They mainly use the Water Requirement Satisfaction Index (WRSI) in drought monitoring.

The standard approach to evaluate rainfall deficit is to define the occurrence of rainfall deficit relative to a crop-specific standard. In this approach, one compares the water supplied by rainfall (or irrigation) against the water requirements of a particular crop as both components vary through the season. At the end of the season, a numerical index is formed, the WRSI (Water Requirements Satisfaction Index), which is 100 in case the crop water requirements are fully satisfied through the season and increasingly below this value the more the rainfall is unable to satisfy them. This approach runs a simple water balance model with a 10-day time step. Rainfall is monitored from the beginning of the season, and at each time step, the rainfall (plus any water stored in the soil) is compared to the water requirements of the crop. If this exceeds the crop requirement, the excess is added to the soil; if it is below the crop requirements, a deficit is registered. Deficits are added throughout the season, and at the end, the WRSI is calculated as:

WRSI = 100 – (Total Deficit / Total Crop Requirement)

This WRSI is 100 for seasons with an optimal water supply (no deficits) and would be 0 for no rainfall. In practice, values below 50 generally correspond to a complete crop failure. The occurrence of significant impacts on crop production is evaluated by deriving the magnitude and frequency of deviations of the WRSI from a reference value, its medium term average value. Deviations from the average are related to qualitative rainfall deficit levels as follows:

Mild rainfall deficit	:	WRSI within 80-90
Moderate rainfall deficit	:	WRSI within 70-80
Severe rainfall deficit	:	WRSI below 70

This information is usually computed and available at the MSD head office however, it is hardly disseminated to districts.

4.4.4 Drought Risk Analysis used by scholars

Remote sensing and Geospatial Information System (GIS) provide timely information and datasets such as precipitation, soil moisture, vegetation and land cover, total water storage necessary for drought-related evaluations. Remote sensing and Geospatial Information Systems technique is a viable alternative in detecting, monitoring, assessing and management of drought events.

Drought Indices commonly used by scholars in Zimbabwe include Vegetation Bases Indices. These reflect the vegetation conditions which are indicative of underlying soil moisture content hence suitable for agricultural drought monitoring. The indices represent the state of vegetation in an area and are more considered and approved by scientist as an essential parameter in agricultural fields monitoring weather effects estimation, biomass and crop yields calculations, monitoring of droughts conditions and determination of vegetation vigour.

Table 8: Drought Risk Analysis Methods Used by Scholars

Index	Description/Formula	Rationale	Reference
Normalised Difference Vegetation Index (NDVI)	Based on GIS and RS NDVI is a ratio of red band (RED) and Near Infrared (NIR) given as NIR-RED/NIR+RED	Vegetation stress caused by drought conditions is closely related to weather conditions	-Frischen et al., 2019 -Mutowo G and Chikodzi, D 2014

			-Makaudze, E.M. and Miranda, M.J., 2010
Vegetation Condition Index (VCI)	VCI is derived from the NDVI by scaling values between minimum and maximum values over a defined time period to detect plant stress (VCI = ($NDVI_{max}$ − $NDVI_{min}$)/($NDVI_{max}$ + $NDVI_{min}$	useful for making relative assessments and detecting drought dynamics during a season	-Frischen et al., 2019 -Mutowo G and Chikodzi, D 2014 -Kuri, F. et al. 2014
Temperature Condition Index (TCI)	(TCI = (Tmax − T)/(Tmax − Tmin) × 100)		Frischen et al., 2019
The Vegetation Health Index (VHI)	Derived from both the VCI and TCI (VHI = αVCI + (1 − α) TCI), where α refers to the relative contribution of the VCI and TCI		Frischen et al., 2019

The Bindura University of Science Education and the Civil Protection Unit secured funding from the World Bank to work on a drought risk analysis project. This project has not started yet and was delayed by the lockdown. In the analysis, they will focus on the Standardised Precipitation Index (SPI) and Palmer Drought Severity Index (PDSI). Some scholars have also used these indicators, as shown in Table

Table 9: Scholars who Used SPI and PDSI

Index	Rationale	Reference
Standardised Precipitation Index (SPI)	SPI index is used to characterise meteorological drought on a range of timescales. On short timescales, the SPI is closely related to soil moisture, while at longer timescales, the SPI can be related to groundwater and reservoir storage.	Manatsa et al. 2010 Mutowo G and Chikodzi, D 2014
Palmer Drought Severity Index (PDSI)	PDSI provide measurements of moisture conditions that are standardised so that comparisons using the index can be made between locations and between months	Frischen et al., 2019

4.5 Drought Exposure Analysis Methods

Exposure of agricultural systems to drought was computed with a land use/land cover (LULC) dataset differentiating between rain-fed and irrigated agriculture in Zimbabwe

4.5.1 Vulnerability Annual Assessment

Since 2014, Zimbabwe has been undertaking annual Vulnerability assessments. This is also a means to assess the impact of drought risk. The overall purpose of the assessment was to provide an annual update on livelihoods in Zimbabwe's rural areas for the purposes of informing policy formulation and programming appropriate interventions.

The specific objectives of the assessment were:

1. To assess the impact and severity of Drought on rural livelihoods.
2. To estimate the population that is likely to be food insecure in a given consumption year, their geographic distribution and the severity of their food insecurity
3. To assess the nutrition status of children of 6 – 59 months.
4. To describe the socio-economic profiles of rural households in terms of such characteristics as their demographics, access to basic services (education, health services, protection services and water and sanitation facilities), assets, income sources, incomes and expenditure patterns, food consumption patterns and consumption coping strategies.
5. To determine the coverage (accessibility, availability and quality) of humanitarian and developmental interventions in the country.
6. To determine the effects of shocks experienced by communities on food and nutrition security.
7. To measure resilience at all levels and identify constraints in improving their resilience.
8. To identify early recovery needs in order to determine short to long term recovery strategies.
9. To assess the medium and long term (future) sources of vulnerability and risks to food and nutrition security.

Methods used

ZimVAC, through multi-stakeholder consultations, developed an appropriate assessment design concept note and data collection tools informed by the assessment objectives.

- The primary data collection tools include the structured household tool and the District key informant tool.
- ZimVAC national supervisors (including Provincial Agritex Extension Officers and Provincial Nutritionists) and enumerators are recruited from Government, United Nations, Technical partners and Non-Governmental Organisations. These undergo training in all aspects of the assessment.
- The Ministry of Health and Child Care is the lead ministry in the development of the Infection, Prevention and Control (IPC) guidelines for the assessment.
- The Ministry of Local Government, through the Provincial Development Coordinators' offices, coordinates the recruitment of district-level enumerators and mobilisation of provincial and District enumeration vehicles.

Data collected

Data were collected to cover the following thematics areas, Education, Health, Water Sanitation and Hygiene, Nutrition, Agriculture and other rural livelihoods activities, Food Security, Shocks and stressors, Social Protection, Markets, Gender-Based Violence, and Cross-cutting issues such as gender

4.5.2 Lean Season Assessment

Lean season assessments are normally undertaken to update the ZimVac reports at the peak of the hunger period. Key objectives include updating the state of food and nutrition security within rural and urban areas; analyse the resilience capacity of households and their ability to cope with the shocks; assess the performance, in terms of coverage, targeting, adequacy and predictability of the current food and nutrition interventions; assess the performance of the season, rainfall at the time of assessment, availability of inputs, the functionality of food markets in the consumption year.

Lean Season Assessment collected data using a three pronged approach, that is, review of existing food and nutrition secondary data and district Focus Group Discussions (FGDs) and a household survey. The assessment focuses on the rainfall season quality, crop and livestock condition, food and livestock markets; household income sources and livelihoods strategies; domestic and production water situation; child nutrition; food and nutrition interventions, shocks and hazards and food security.

4.5.3 Crop and Livestock Assessment

Given the vulnerability of Zimbabwe to food insecurity, the MAMID undertakes two types of assessments for early warning: first and second round crop and livestock assessments (February and April) and the food balance sheet supported by COMESA.

The crop and livestock assessment is done in two phases, the first round during the first quarter of the season to establish the area planted and growing condition for all crops and the condition of grazing for livestock. The second-round crop and livestock assessment is done during the last quarter of the season to estimate the yield and condition of livestock. The survey samples farmers and extension officers who fill in questionnaires. Verification, data entry, analysis and report writing is carried out by technical officers. The assessment is carried out and funded by the Ministry of Lands, Agriculture, Water, Climate and Rural Resettlement MLAWCRR.

During the current agricultural period, the Government adopted modern technology to undertake the annual national crop and livestock assessment. For the first time, production is being evaluated electronically using the new system — Agricultural Production Form (APF) — which captures an individual farm's precise productivity in real-time and feeds data collated from districts into a national mainframe in Harare. The pre-harvest assessment exercise enables authorities to ascertain the exact hectarage put under different crops during the current season in each District countrywide. The digital platform is being used to track individual farmers' precise hectarage and expected production levels. The advantage of having this system is that we will be able to trace the farmers' production and also the challenges they are facing, for example, if they are having challenges with irrigation or machinery.

Other drought Monitoring methods

The Zimbabwe National Water Authority (ZINWA) is a parastatal institution which falls under the Ministry of Environment, Water and Climate has 342 river monitoring stations. However, not all these stations are used for flood purposes. Only 37 are used for floods purposes. Dam levels are monitored weekly, which constitute more than 80% (149 dams) of the total storage in the country. ZINWA has linkages with the Southern African Development Community (SADC) Earth Satellite Observation Monitoring Station and a flood monitoring software is being developed by the University of Zimbabwe.

Provide an inventory of drought forecast models addressing the following key questions

4.6 Inventorisation of Drought Forecast Models

MSD is the only institution responsible for weather forecasting. It does this by bringing academia and other experts together so that they come up with weather forecast, particularly the OND and JFM season. Although there are no other institutions providing weather forecast, we noted that there is expertise within the country to do weather forecast, but they do not have the mandate to disseminate weather information, for example, the Department of Physics at the University of Zimbabwe. In forecasting, weather, the following models are used: European Centre for medium-range weather forecast, National Centre for environmental predictions and Ventusky. Non-government organisations work in collaboration with MSD on projects that require weather forecast – we noted the following: World Vision, Red Cross, Oxfam, Plan International, Southern Alliance for Indigenous Resources (SAFIRE).

Table 10: Drought forecasting models

Question	European Centre for medium-range weather forecast	National Centre for environmental predictions	Ventusky
• What kinds of forecasts are produced, or which methods, datasets and indicators are used to produce the forecasts? • The kinds of forecast produced	Hydrological prediction Early predictions of events such as heatwaves, cold spells and droughts, as well as their impacts on sectors such as agriculture	Aviation weather forecast Storm predictions Space weather predictions Ocean weather predictions Hydrological predictions	Aviation weather forecast Storm predictions Space weather predictions Ocean weather predictions Hydrological predictions
• The datasets and indicators used	Datasets: Temperature, Humidity, wind speed and direction Indicators: Temperature changes over time, humidity changes over time, cold air and hot changes over time and its direction strength and depth	Datasets: Temperature, Humidity, wind speed and direction Indicators: Temperature changes over time, humidity changes over time, cold air and hot changes over time and its direction strength and depth	Datasets: Temperature, Humidity, wind speed and direction Indicators: Temperature changes over time, humidity changes over time, cold air and hot changes over time and its direction strength and depth
• What is the format of issuance? Deterministic or Probabilistic -	Probabilistic	Probabilistic	Probabilistic
• How often is the forecast produced?	24 hours	24 hours	24 hours
• Is the forecast generated by a computer model or produced by human estimates?	uses computer based mathematical models of the atmosphere and oceans to predict the weather based on current weather conditions	Generated by a computer model and experience of the scientists	Generated by a computer model and experience of the scientists
• What is the lead time for each forecast, i.e. what is the time between forecast issuance and the shock?	medium-range forecasts, predicting the weather up to 15 days ahead monthly forecasts, predicting the weather on a weekly basis 30 days ahead Seasonal forecasts up to 12 months ahead	Monthly to seasonal climate outlook issued 2 weeks to 13 months in advance Issue 6 – 10 days and 8 – 14 day outlook maps probabilities of temperature Excessive heatwaves index and wind chilli index issues every day	
• What regions are covered by the forecast?	Global	Global	Global
• What is the resolution in space and time	Resolution in time: 24 hours Resolution in space: 9 m and 18 km for ensembles	Resolution in time: 24 hours Resolution in space: 50km	Resolution in time: 24 hours Resolution in space:50 km

The skill of the forecast is at 75%, and this is estimated by comparing the forecast given and would have eventually in term of weather.

5 CONCLUSIONS

Climatic conditions have been changing over time and scientific evidence shows that mean global temperatures have increased and are further predicted to increase at a rate of 0.05°c per decade and rainfall will decrease by 5-10 percent per year (Sánchez-Lugo, Berrisford, Morice, & Argüez, 2018; IPCC, 2014). These predictions imply that the adverse effects of climate change will increase in both intensity and frequency. This is projected to reduce staple crop yield by over 50% (IPCC, 2014) and will plunge hundreds of smallholder farmers into chronic food insecurity, malnutrition, and abject poverty. Current efforts have been directed at assisting smallholder farmers to adapt and manage the effects of climate change on their food security situation. There is spatial variation on the impact of drought across the country. The most affected districts are in the Southern parts of the country and also along the Zambezi valley which tend to experience persistent droughts

Climate forecasting information is mainly done by the MSD in collaboration with other scholars and such information is passed to farmers through the media. The use of Indigenous knowledge, though important to the local communities in predicting drought risk has been sidelined. The country has a comprehensive multi-stakeholder approach to monitoring the effects of climate change. There are useful drought risk monitoring methods used by academics which are not yet mainstreamed into the multi-stakeholder systems.

RECOMMENDATIONS

Although the MSD provides weather forecast regularly, study by Zamasiya et al, (2019) shows that only 67% of farmers access such information. The reminder relies on indigenous knowledge for drought risk forecasting. We propose that the project working with climate change experts can amalgamate indigenous knowledge in drought risk forecasting.

The Department of Agricultural Research and Extension undertakes drought risk monitoring using tools such as water requirement satisfaction. However, the expertise to undertake crop requirements satisfaction need to be further strengthened as some extension officers did not have the expertise to do so.

While implementing this project, it is important to take note of similar initiatives and seek beneficial collaborative relationships. For example, The Zimbabwe Red Cross Society is implementing similar projects in Matebeleland North and South Provinces and BUSE in partnership with CPU with funding from World Bank are also in a process of doing a similar project.

Provide a prioritization of the regions based on the results of the analysis.

Based on evidence from scientific studies reviewed by this study, as well as discussions with key informants, we have come up with the following districts as recommendable for disater response interventions. The choice mostly considers the level of proness to chronic droughts and the severity of food insecurity in the district.

Proposed Regions	**Recommended district**	**Drought prone classification**	**Remarks**
Matebeleland North	Tsholotsho	Mild	Already selected
	Lupane	Mild	Proposed to replace Umguza, which is classified as moderate
Matebeleland South	Beitbridge,	High severe	Proposed to replace Mangwe, which is classified as moderate
	Matobo	High severe	Already selected
Masvingo	Chivi,	High severe	Already selected
	Mwenezi	High severe	Already selected
Manicalands	Buhera,	Mild to Moderate	Already selected
	Chimanimani	High severe	Already selected
Mashonaland Central	Mbire	Mild	Already selected
	Rushinga	Mild	Already selected
Mashonaland east	Mudzi	Mild	Already selected
	UMP	Mild	Already selected
Midlands	Mberengwa	Severe	Proposed to replace Gokwe South which is classified as moderate
	Gokwe North	*Mild*	Already selected
Mashonaland West	Makonde	Mild	Already selected but concentrate on the old communal areas where rainfall is very poor and erratic
	Sanyati	Mild	Already selected

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APPENDIX

Appendix 1	Terms of reference	Terms of reference.docx
Appendix 2	A gudie for key informant interviews	Appendex 2 Interview guide.docx
Appendix 3	List of key informant interviewed	List of key informant.docx