BUILDING CLIMATE CHANGE RESILIENT COMMUNITIES IN AFRICA

INSIGHTS FROM ZIMBABWE'S URBAN AND RURAL AREAS

KONRAD ADENAUER STIFTUNG

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FOREWORD

Countries in the tropics and global south such as Zimbabwe are experiencing increasing climate induced extremes and change with projections pointing to increasing impacts of these impacts. The related extremes and Climate Change impacts include recent occurrences such as the Tropical Cyclone Idai, that ravaged Zimbabwe, Mozambique and Malawi; recurrent droughts which have affected Zimbabwe over the past three years, prolonged dry spells, erratic rainfall and violent hailstorms. Prior to these catastrophic events, research had long identified how farmers in southern Africa continue to face such vulnerabilities. Furthermore, studies have noted the centrality of Smallholder farmers to agriculture development in Southern Africa for the unforeseeable future, despite their reliance on rainfall for agriculture.

Equipping and preparing smallholder farmers with knowledge and resources on how to adapt and mitigate climate change, at the same time remaining food and income secure is critical. Urban areas have also not been spared by the negative impacts of Climate Change. Key among these include water shortages due to desiccation of water traditional water sources such dams, rivers and other natural aquifers; violent hailstorms; heat waves and hydro-power shortages due to dwindling water levels in Kariba dam. Hidden impacts include job losses, suppressed industrial activity, poverty and the ever rising food and raw material prices which could potentially create instability. Trying to understand and proffer solutions to these impacts calls for both multi-stakeholder and multi-disciplinary efforts. This resilience-building effort requires both rural and urban focus. This book brings together authors including economists, sociologists, social workers, lawyers, agriculturists and natural scientists from different institutions and focus areas to address these issues. Key stakeholders and practitioners including government departments, development partners, civil society, and academic are invited to utilise this book, as one of the resources to manage Climate Change.

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CONTENTS

CHAPTER **01**

EFFECTS OF CLIMATE CHANGE: AN INTRODUCTION

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INTRODUCTION

Climate change presents a ubiquitous challenge across the globe since the 1800s. Literature defines climate change as much more than a crisis but chronic and long term changes in the earth's climate and weather patterns (Hulme 2016). Despite its existence, there have been conflicting views over such and the recent contestations during and after the Paris Climate Agreement in 2015 are testimony to this continued acrimony, even if supporting evidence exists. Whatever arguments one makes, the setting up of the Intergovernmental Panel on Climate Change in 1988 is a clear testimony of its existence and importance. Green House gasses, largely carbon dioxide, have been pointed at as the major drivers of global warming, which in turn causes climate change. Often cited indicators of climate change include droughts as driven by the El Nino and floods resulting from the La Nino effect. While levels of effects in the developed North and developing South, are debatable what seems obvious is that the latter countries are more vulnerable given their heavy dependence on rain-fed agriculture and less diversified economies. In short, less developed countries lack the necessary resilience capacities and competences to the negative effects of climate change.

There is a consensus among scientists, economists, and policy makers that the entire globe is facing a real and serious long-term threat from climate change (Buckland, 1997; Kinuthia, 1997; Hansen et al, 2007; Matarira et al, 1995). Africa has been reported to be experiencing increased water stress, decreased yields from rain-fed agriculture, increased food insecurity and malnutrition and an increase in arid and semi-arid land as a result of climate change (IPCC, 2001; 2007; 2012). These changes in rainfall patterns, temperature, and other extreme weather events are projected to increase crop failures, pest and disease outbreaks, and degradation of land, forestry, fisheries and water resources in Sub-Saharan Africa (Seneviratne, 2012; IPCC, 2014).

Various studies show that climate change is already having strong adverse impacts on poor smallholder farmers' livelihoods who derive their livelihoods from rain-fed agriculture in the region (IPCC, 2012). Boko *et al*., (2007) predict that in southern Africa, mean annual temperature is going to rise, the frequency and intensity of cyclical droughts would increase while the overall rainfall pattern will decrease by over 30 percent by the year 2020. Studies show that the changing climate is already negatively impacting on rain-fed per capita food production, household food security and poverty reduction efforts in Southern Africa (Gwimbi, 2009). Most southern African economies hinge on rain-fed agricultural production with the sector contributing 30-40 percent of the Gross Domestic Product and providing livelihoods to over 70 percent of the population (Below, 2010). Smallholder farmers in southern Africa are vulnerable to climate change because of low adaptive capacity and the presence of multiple stressors such as endemic poverty, dysfunctional market institutions, soil fertility decline and complex climate systems (Gwimbi, 2009). Literature shows that because of climate change and variability, rain-fed staple cereal crop yields could fall by 50 per cent by 2020, food prices would increase by over 40 per cent while net crop revenues could fall by up to 90 per cent by 2100 (Gbetibouo, 2009: Mutekwa, 2009). As such, failure to manage climate change by developing countries will be met with a sharp decline in food production, famine and unprecedented setbacks in the fight against deepening poverty. This evidence suggests that smallholder farmers can only be less vulnerable to the effects of climate change if they adapt. Studies have shown that adaptation to climate change by smallholders has the potential to substantially reduce the adverse of climate change (Mensah et al 2010; Gbetibouo, 2009).

Some of the effects of climate change on smallholder farmers in Sub-Saharan Africa would be shrinkage in the area for maize and soybeans by 30% and 60% respectively by the end of the 21st century (Rippke, et al., 2016). These crops are some of the major livelihood crops in the region (Tessema, Joerin, & Patt, 2019). The shrinkage in the land area is caused by shifts in the agricultural range of crops due to the effects of climate change (Adego, Simane, & Woldie, 2019).

Female heads an already highly vulnerable food insecure group will likely the suffer most due to heavy reliance on climate sensitive systems particularly rain-fed agriculture and natural resource for food and income (Kotir, 2011, Horrel et al, 2006; Tibisegwa, 2015, Mallick et al, 2010; Alhasan, 2019). The high levels of poverty marked by low incomes associated with female heads will also impinge on their adaptive capacity (Buvinic et al, 1997; Kates 2000; Schulze 2010). The current global trends point to the increase in the numbers of female heads, with the majority of them in Sub-Saharan Africa and concentrated in rural areas (Horrel & Krishnan, 2006). This will heighten the magnitude of food insecurity among female headed households the thus making it difficult for the already resource constrained governments to effectively respond. Existing evidence already reflect women and men as disproportionately affected by climate change female heads in South Africa female as more likely to suffer food insecurities due to weather related crop failures resulting in reduced household consumptions levels as opposed to male counterparts.

From the tropics to the polar regions, climate and weather have powerful direct and indirect impacts on human life (UNFCCC, 2007). Climate change related events have endangered health as well as destroyed property and livelihoods. A plethora of parasitic, viral, and bacterial diseases are sensitive to climate whether through their geographic distribution, seasonality, inter-annual variability, or temporal and spatial trends (Thompson et al 2018). Changes in climatic variables, especially temperature, affect the life history of biting insects and consequently vector-borne diseases (Brand and Keeling 2017). In general, most biological processes occur at a faster rate at higher temperatures, although not all processes change in the same manner. Changes in the global climate bring a range of risks to health, from deaths in extreme high temperatures to changing patterns of infectious diseases.

Besides climate change has had serious effècts on natural resources management. One of the global solutions to climate change is 'reducing emission from deforestations and forest degradation' REDD+. This involves paying forest owners in developing countries to keep their forests instead of cutting them down and rewarding them for resulting reduction in greenhouse gas emission. The efforts to manage communal forestry as a carbon sink is complicated by the common property nature of the resources. Climate change and climate variability have also resulted in the drying up of large trees at an alarming rate. One the chief cause is the reduction in soil moisture due to persistent and extended droughts. The rampant destruction of vegetation cover due cutting down of trees for household use, clearing agricultural land and destruction of by wildlife, particularly elephant has remained a major threat to the few trees remaining in the district. Persistent droughts have threat water sources which have had a negative effect on livestock production, fisheries, irrigation schemes and water and sanitation programmes.

This book, therefore, contributes to the growing body of literature in support of the understanding that climate change is real. Firstly, the book starts by showing how climate change is happening in Zimbabwe. Secondly, we show the effects of climate change and thirdly how local communities, who are experiencing or perceiving its effects are faring in their endeavours.

This book is a result of a workshop that was organised by the Centre for Applied Social Sciences (CASS), a leading Social Science Research and Teaching Department at the University of Zimbabwe. The workshop was funded by the Konrad Adenaer Stiftung (KAS) and its main idea was for participants to share ideas on Climate Change in Zimbabwe on 18th to the 19th July 2019 at the Celebration Centre in Harare, the country's capital. The workshop brought together various stakeholders with an interest in climate change. These included leading Zimbabwean academics, officials from the Ministry of Environment, researchers, students and farmers, as well as environmental lawyers. Apart from sharing ideas on climate change research going on in Zimbabwe, participants at the workshop agreed on two critical things. First was to compile the various presentations into a book. The second was to launch a Climate Change Research Platform comprising most of the participating stakeholders, with CASS acting as the hub. This book is therefore based on the selected evidence-based presentations that were shared during the two-day workshop. While global climate change might be pointing in different political directions, the contributions making this book are unanimous in that climate change is a living reality that is already threatening human livelihoods, human health and renewable natural resources. Also pointed out in the book is that there are variations in the way climate change as a socio-economic phenomenon is interpreted in different settings. For example, its impacts are less perceived in urban areas where priorities tend to be focused on employment, which and naturally so, is the major livelihood opportunity. Critical also is the point, which has been raised in many for a and often ignored by development and policy makers, that solutions to climate change are not the same for every situation but rather need to be context based. The book takes a step further than just presenting cases and effects of climate change in Zimbabwe, but points to some key recommendations or strategies that might increase the ability of affected individuals, households and communities to adapt to climate change. These are viewed as having the potential to minimize the potential damage from climate change on food security, human and animal health biodiversity and ecosystems.

ON METHODOLOGY

There is no doubt that case study results are influenced by the way the studies are conceptualized, executed and analysed (Cresswell 2014). The common philosophy that bound most of the independent studies presented in this book by different authors seems to be the desire and volition to understand the nature of climate change as a socio-economic phenomenon; the manner or how climate change is affecting or perceived by both societies and individuals; how people are responding and social capital at their disposal to deal with the emerging phenomenon (climate change) and finally how best this can be enhanced. While literature review appears central to most of the case studies, all cases seem to be strongly influenced by a participatory or ethnographic flare. That is going where the action is happening and hence the location of the studies in different settings as diverse rural Dendenyore in Hwedza District to urban Masvingo. Key and inline with CASS tradition, is locating research where the phenomenon is happening. Also important in all the chapters that make this book is the guidance by praxis-combining theory with concrete solutions based on observations and experiences from the ground. Issues of keeping up with academic or scientific scholarship are adhered to in all the studies maintain the validity of data. The studies are guided or framed around scientific study area identification; sampling procedures (including multistage, random and purposive techniques) and analyzing data from samples as large as 400 informants and increased use of longitudinal data, in some cases dating back 40 years. The studies also show the desire by climate change scholars whose case studies are presented in this book to employ both qualitative and quantitative data, a move that is in tandem in the new desire among socio-environmental scientists to deploy mixed methods research methodologies, once rebuked as academic eclecticism or inconsistency. We seem to see continuity among case studies presented in this volume that there is value in combining both subjectivity and objectivity, and the fecundity of triangulation, not only of research methods but also in issues such as data analysis, reflexivity included. Common across the studies, is the almost universal use of participatory methodologies, especially Focus Group Discussions and Key Informant Interviews, pointing to the institutionalization of research methods that give more value and appreciate local people's experiences and aspirations. In short, we see the increased application of both smart technology or computer added and traditional grounded theory-based thematic data analysis.

STRUCTURE OF THE BOOK

While this Chapter One has provided some background in terms of climate change debate, methodological issues, the rest of the book is organized as presented below.

Chapter Two by Mashura explores changing weather patterns (rainfall and temperature) and effects these are having on important crops such cotton, maize, sorghum, soybeans, tobacco and sugarcane, all important for both food security and employment in Zimbabwe. In Chapter Three, Caren Pindiriri investigates challenges or independent and dependent variables or drivers which lead to what he describes as "*farmers' captivity to traditional technologies*", meaning failure by rural farmers to adopt available technologies in response to climate change that is affecting their agricultural productivity and food security.

The issue of climate adaptation is also followed up in Chapter Four by Zamasiya, Nyikahadzoi and Mukamuri who explore challenges faced by smallholder farmers in Dendenyore, a typical communal farming area where communal land tenure and access to information are critical to climate change adaptation. The former driver of climate change is however not fully explored in the book and perhaps a subject for future studies. In Chapter Five, Ruparanganda and Nyikahadzoi's case study draws on regional literature and the Zimbabwean cases to demonstrate the disparate effects climate change is having on female headed households when compared to those headed by their male counterparts. The Chapter further explores survival strategies employed by female headed households to make up for dwindling food productivity due to climate change. These include though neither sufficient nor easy nor guaranteed for women, consumption of wild fruits and vegetables, as well as engaging in labour intensive irrigation. Chapter Six by Mabvurira and Chikwaiwa, brings into the book a non-traditional research area, that of the effects of climate change on the livelihoods activities of former commercial farm workers in Mazowe South in Zimbabwe. This group of people represent in Zimbabwe a hugely marginalized group of people who used to earn, albeit not modest, but, guaranteed from of livelihood by working on former white-owned commercial farmers. Their predicament changed around the year 2000 when the country embarked on a massive land reform programme which saw former private land being given to Africans. The disruption resulted in unemployment for thousands of former farmworkers most of them of Malawian origin. The new black farmers have failed to absorb these former migrant workers because of several reasons most of which are beyond the scope of this book but have been discussed elsewhere (Phimster 1974; Moyo 2000; Rukuni et al., 2006; Scoones et al., 2010). Combined with weak ancestral ties in Zimbabwe and unemployment this group was left with no other option but to engage in petty income and food generating activities such as brick moulding, sale of commodities and gardening. The advent of climate change has further caused further disruption as explained in the chapter. The role the media, both public and private, plays in development and driving agendas is well known (Adekoya & Ajilore2012). Key among the case study finding is that climate change mitigation does not rank high on participants' list of concerns in an urbanising context. This finding, as we comment in our conclusion calls for a nuanced understanding of climate change issues and solutions in a context-sensitive manner. Through the use of longitudinal data, Chapungu explores the effects of climate change on malaria prevalence (Chapter Eight). This case study is more relevant now than when it was conceptualized and executed because of the situation the world is in due to COVID-19 which resulted in over a million human deaths; disrupted commerce and social ties. The chapter, though not explicit, points to the significant role climate change can play in reshaping disease trajectories in novel ways. Is climate mitigation easy? Phiri et al., in Chapter Ten show how climate change is affecting the fishing industry in Lake Kariba, a resource shared by Zimbabwe and Zambia and supporting thousands of people engaged in kapenta fish value chain. The study is awakening in the sense that it analyses data on lack level and temperate, both important variables are driven by climate change and shows how these affected yields. Chapter Nine by Mangwanya and Dzingirai evaluates the performance of the Kariba Carbon Redd+ Project in its efforts to mitigate on tobacco and settlement driven deforestation in the context of climate change. The results from the case study points to increased rather than certainty, especially with regards profit-motivated private sector-led climate mitigation projects.

Last but not least, in Chapter 11, the book presents some recommendations or what could be viewed as strategies to promote both mitigation and adaptation to climate change. This should be read with the hindsight the country's climate change policies are more geared towards adaptation rather than mitigation (Mr Moyo's keynote presentation. The recommendation, point to issues such as the greater need for innovative collaboration involving individuals, communities and policy makers; sector sensitive climate change monitoring; the need to enhance food production systems, particularly in the agricultural sector (drought-tolerant crops and gender or female-headed households focus; awareness and education; extension; social learning; adaption support; diversification; incomes support;

social and economic capital enhancement; inclusivity and innovation; resilience building of both systems and people (including transformative aspects) (see also Nyikahadzoi, Mhlanga and Haller, 2014); less dependency on the natural resource base and turn to alternatives

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CHAPTER **02**

CLIMATE CHANGE AND CROP PRODUCTION IN ZIMBABWE: AN ERROR CORRECTION MODELLING APPROACH

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ABSTRACT

This study aims to estimate the effects of climate variables (rainfall and temperature) on crop yield in Zimbabwe. In particular, the study analyses the impacts of climate change variables on yield per hectare of eight selected crops namely cotton, maize, millet, sorghum, soybeans, sugarcane, tobacco and wheat. It employs a Ricardian approach with error correction modelling technique based on time series data for the period 1961-2016. Crop yield per hectare is regressed on climate and other socio-economic variables. Our results indicate that there is a non-linear relationship between annual rainfall and production of maize, cotton, soybeans and sugarcane. Excessive rainfall could result in reduced maize, cotton and soybeans yields, while very little rainfall could be detrimental to sugarcane production. There is also a non-linear relationship between temperature and yields of cotton, maize and tobacco. For tobacco, excess temperature would be detrimental to productivity while for cotton and maize which are negatively affected by high temperature very low temperatures can result in crop failures. Irrigation has a positive impact on maize, soybeans, sugarcane, tobacco and wheat, but negatively affects cotton yields. Agricultural population (share of agricultural population working agriculture) has a negative effect on cotton production and a positive effect on sorghum output per hectare. Fertiliser use could only positively influence cotton, tobacco and wheat output, but not the other crops. Climate change effects are driven by both increases in temperature and decreases in rainfall, which implies that irrigation and planting of drought-resistant crops that are less sensitive to climate shocks would mitigate the harmful effects of climate change.

Key Words: *Error correction, Climate Change, Crop production, Cointegration.*

INTRODUCTION

Climate change has become a global challenge and more so a serious cause for concern for developing countries, particularly in Africa. Intergovernmental Panel on Climate Change (IPCC) reports predicted that African countries will continue to experience frequent extreme weather events like floods and drought, rising temperatures and unreliable rainfall (IPCC, 2007; 2014). The increasing evidence that countries will continue to experience changing climatic conditions has added urgency to the need to estimate the effects of these changes. Quantifying and knowing the effects of climate changes will help identify and develop practical approaches to mitigate the adverse consequences of climate change.

Most African countries have economies which depend on agriculture for food security and employment. The agriculture sector accounts for a larger proportion of the population in rural areas who are engaged in small-scale and subsistence agricultural activities which are exposed to various climate change shocks. The predicted changes in climatic conditions have more impact on African given the fact that most of the countries are located on lower latitudes and already enduring low precipitation and higher temperatures. Besides the region depends on climate-sensitive rain-fed agriculture (IPCC, 2014). Previous studies show that crop productivity will be negatively affected by further increases in temperature and decrease in precipitation levels (Jidauna, Dabi & Dia, 2012; Akintunde, Okoruwa & Adeotu, 2013; Nhemachena, 2014; Eregha, Babatolu, & Akinnubi, 2014; Ochieng, Kirimi & Mathenge, 2016)

Local ecosystems offer a primary source of livelihood for the majority of the people around the world. According to ZimStats (2019), about 69 percent of the population in Zimbabwe live in rural areas where their livelihoods evolve around climate-sensitive rain-fed small-scale and subsistence farming and other agriculture related activities. The productivity of livelihood for most rural poor is highly sensitive to climate shocks like increases in temperature, reduced rainfall patterns and periodic flooding and drought. The vulnerability of the majority of the rural poor in Zimbabwe is exacerbated by limited of access to land resources, inadequate water, low technology and education levels, high HIV/AIDS spread and institutional mismanagement (Nhemachena, Hassan & Chikwiriza, 2010).

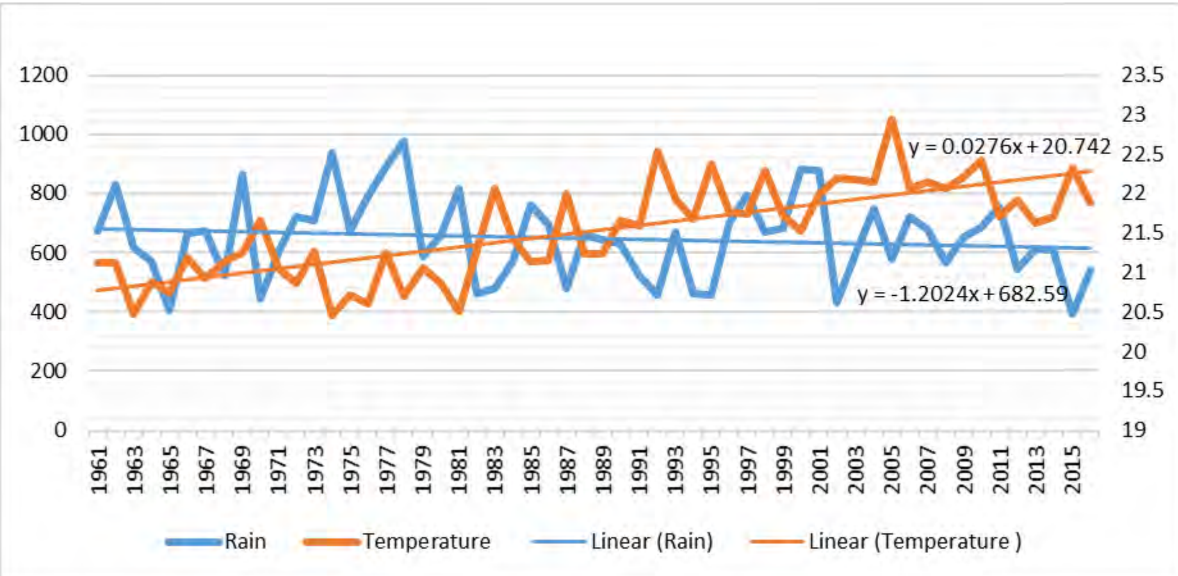
Agriculture continues to be the backbone of the Zimbabwean economy, accounting for 11-22% to gross domestic product (GDP) for the past two decades. In addition, the sector employs about 70% of the population, provides 60% of the raw materials for the manufacturing sector while contributing 40% towards foreign legal tender earnings (World Development Indicators, 2019). Although the agricultural sector continues to be the pillar of Zimbabwe's economy, agricultural policy making has not so far given sufficient attention to the effects of climate change and other related issues. Also, given its relative sensitivity to climate shocks and regardless of its important role in the economy, estimation of the effects of the consequences of changes in climatic conditions is critical. This study aims to measure the effects of climate change on crop productivity in Zimbabwe. The study contributed to the literature by investigating the effects of climate change on different crops using the Ricardian model based on time series analysis. Quantifying the effects of climate change on different crop types shed more light on the impacts of climate shocks on maize which is a staple food, millet and sorghum which are small grains, cotton and tobacco which are export crops as well as wheat soybeans and sugarcane which rely on irrigation for the farming.

TRENDS IN ZIMBABWE'S AGRICULTURAL PRODUCTION AND CLIMATE VARIABLES

Trends in climate variables

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 1961 and 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 1: 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.

Trends in agriculture production

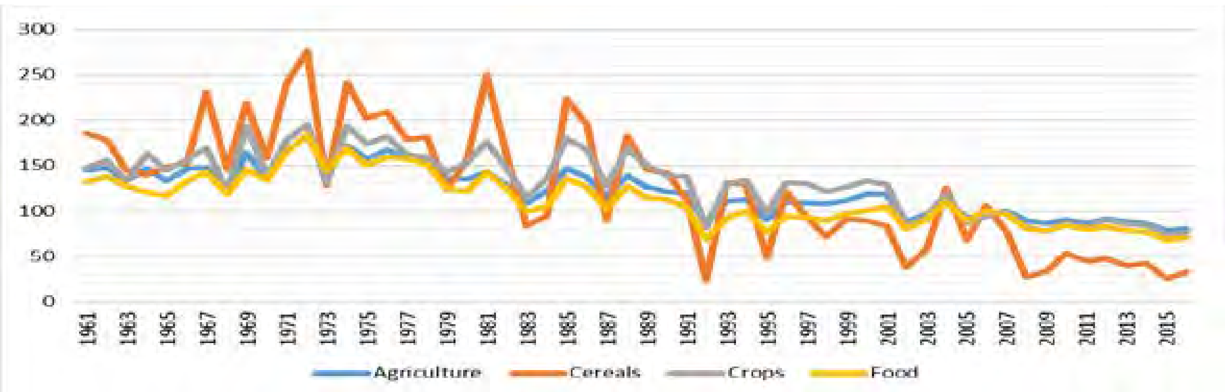
Agriculture continues to be the mainstay of the economy of Zimbabwe as the majority of the population live in rural areas where their livelihood evolves around agricultural activities. The sector has contributed about 11-22% towards the Gross Domestic Product (GDP) for the past two decades (see Figure 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 2 below shows that contribution of agriculture towards the GDP has been fluctuating and declining. The decline could be attributed to low and variable precipitation, reduced soil fertility as a result of floods, lower technology adoption and investment thresholds, shortage of finance and power, poor institutional and physical infrastructure and frequent drought occurrence.

Figure 2: Agriculture value added (% of GDP)

Source: World Development Indicators, 2019

Figure 3 shows agriculture, crops, cereals and food production indices. The trends show that production has been on the downward trend since 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 3: Agriculture, Crops, Cereals and Food Production Indices



Source: FAO Stats, 2019

Figures 4-11 show the trends in the selected crops. The trends of the selected crops show that production of maize (Figure 6), cotton (Figure 10), millet (Figure 11), sugarcane (Figure 4) and sorghum (Figure 5) have been exhibiting the downward trend for the period under study. The decline in production of maize as a staple diet for the country poses a serious threat to national food security and health status. The decline in production of cash crops such as cotton and tobacco also limits development process as the nation loses foreign currency.

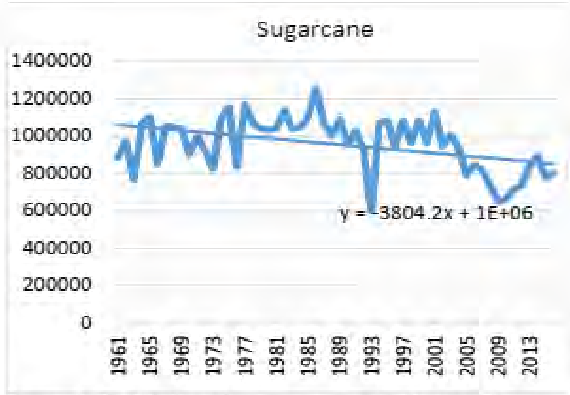


Figure 4: Distribution of sugarcane production tons/ha

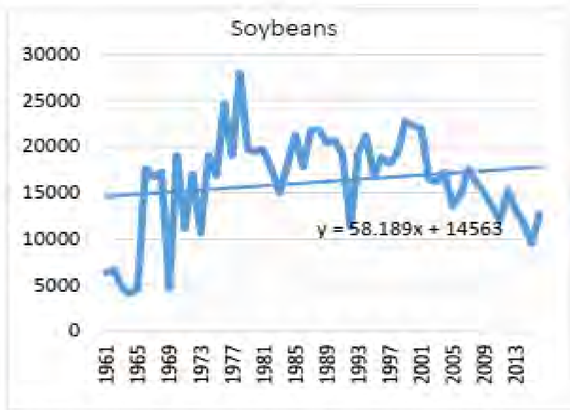


Figure 5: Distribution of soybean production (tons/ha)

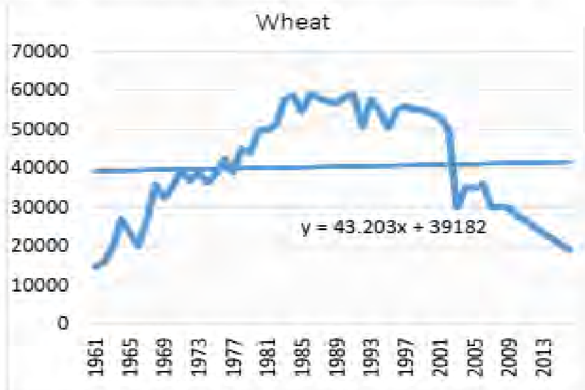


Figure 6: Distribution of wheat production (tons/ha)

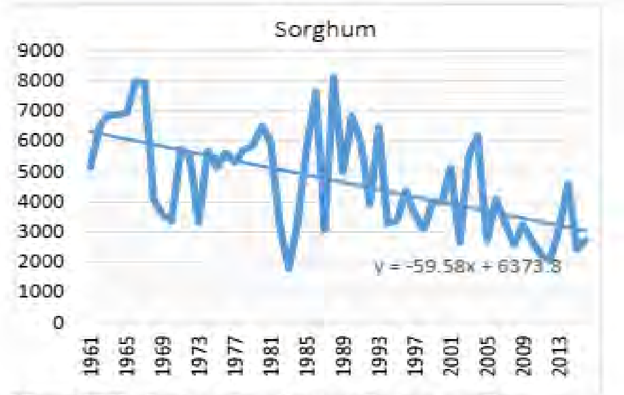


Figure 7: Distribution of sorghum production tons/ha

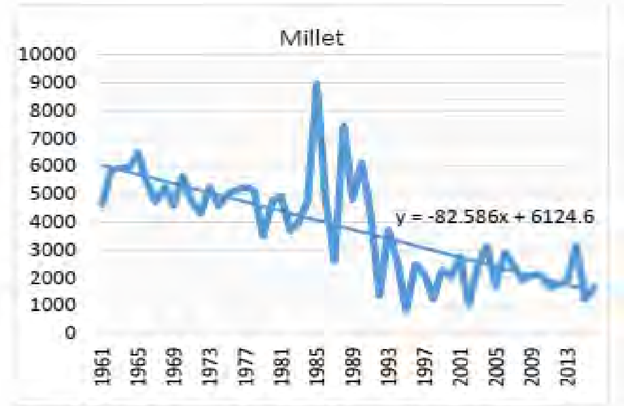


Figure 8: Distribution of millet production (tons/ha)

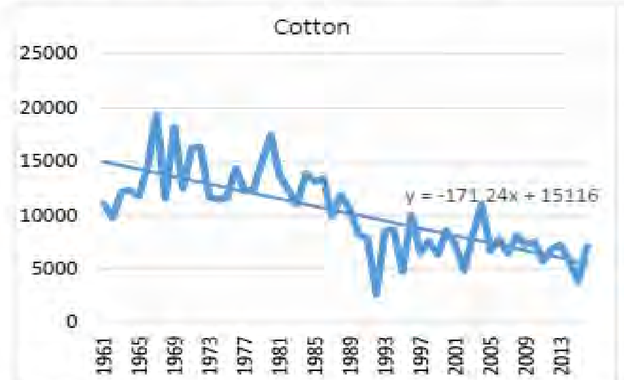


Figure 9: Distribution of cotton production (tons/ha)

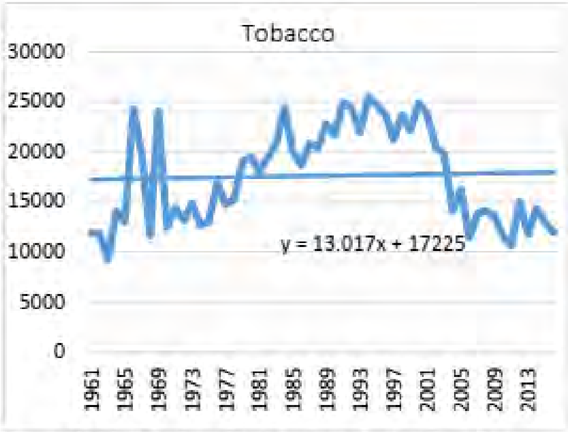


Figure 10: Distribution of tobacco production (tons/ha)

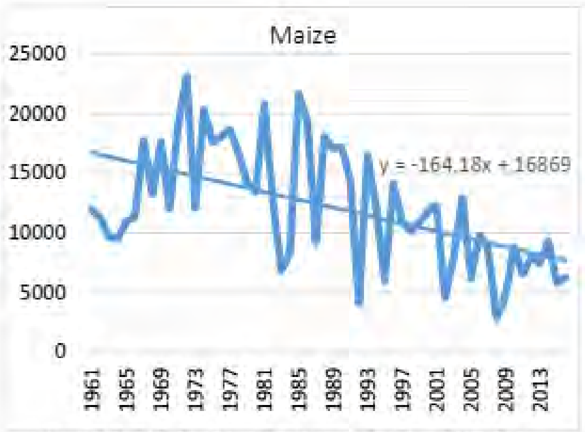


Figure 11: Distribution of maize production (tons/ha)

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 it can be observed from the trends shown by Figure 4 to Figure 11. 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.

BRIEF LITERATURE REVIEW

Climate change has emerged as the major challenge besetting the performance of agriculture sector in Sub-Saharan Africa, mainly because most countries are located on lower latitudes, heavily rely on rain-fed agriculture and have limited capacity to adapt to climate changes (Belloumi, 2014). Several studies have documented the adverse impacts of changes in climate in Africa. Maddison, Manley & Kurukulasuriya (2006) employed a Ricardian approach to examine how farmers in 11 different African countries have adapted to changing climatic conditions. The study simulated the effects of predicted changes in climate while accounting for whatever farmer adaptation strategies that might occur. The results showed that African agriculture is significantly vulnerable to climate change. Specifically, the study reveals that even with perfect adaptation, regional climate change by 2050 is predicted to entail production losses of 19.9% for Burkina Faso and 30.5% for Niger. In contrast, countries such as Ethiopia and South Africa were expected to be less affected, suffering productivity losses of 1.3% and 3% respectively.

Deressa, Hassan, & Poonyth (2005) employed a Ricardian approach to investigate the economic impact of climate change on crop production in South African with special emphasis on sugarcane growing regions. The study found out that climate change has a significant nonlinear impact on net revenue per hectare of sugarcane with higher sensitivity to future increases in temperature than precipitation. Unlike in most scenarios, irrigation did not prove to provide an effective option for mitigating climate change damages on sugarcane production in South Africa. Another study by Deressa & Hassan (2009) investigated the economic impact of climate change on crop production in Ethiopia and found that climate change, among other variables, had a significant impact on net crop revenue per hectare of farmers under Ethiopian conditions. The seasonal marginal impact analysis indicated that marginally increasing temperature during summer and winter would significantly reduce net crop revenue per hectare whereas increasing precipitation during spring would significantly increase net crop revenue per hectare.

Downing (1992), explored the impact of climate change in Kenya, Zimbabwe, Senegal and Chile. The results showed that higher temperature would have a positive impact in highland areas but a negative effect in semi-arid lowland areas. Therefore, the potential food production would increase with rising temperature and rainfall, but in the semi-arid areas, yields would decline as a result of insufficient precipitation. Fischer and van Velthuizen (1996) indicated that the overall impact of climate change on food production in Kenya would be positive but results would vary by region. They also asserted that the increase in production would arise from an increase in carbon dioxide and temperature, provided there would be an increase in precipitation as well.

Kabubo-Mariara and Karanja (2007) conducted a comprehensive study of climate change in Kenya. The study was conducted in 38 out of 46 former districts and analysed the economic impact on crop agriculture, using a seasonal Ricardian model and a crop response simulation model. The analysis was based on different data, long term mean seasonal temperature and precipitation data, long term monthly hydrological data, main classes of soil types, and a cross-sectional household level data. The results showed that climate affects crop revenue. Specifically, the findings indicate that increased winter (June-August) temperature is associated with higher crop revenue, and increased summer (March-May) temperatures has a negative impact on crop revenue. Increased precipitation was found to be positively correlated with net crop yield. The results further show that crop revenue has a non-linear relationship with both precipitation and temperature.

Although several studies explore the impact of climate change on agriculture in Africa, few studies, however, have documented impacts of climate change on Zimbabwe crop production. Among the few studies that were done on Zimbabwe include Mugadza (1994) and Muchena (1994) who investigated the impacts of climate change on crop yields. Their findings show that an increase in ambient temperature by 2℃ and 4℃ would reduce crop yields. Makadho (1996) employed the dynamic growth model to explore the impact of climate change on maize. The results show that maize production in Zimbabwe was expected to decrease by 11-17% under the irrigated and non-irrigated conditions in some regions of agricultural production. The reductions in maize yield were primarily attributed to ambient temperature increases which shorten the crop growth period, particularly the grain-filling period.

Matarira, Makadho & Mukahanana-Sangarwe (2004) study the impact of climate variables on maize in Zimbabwe using the global climate change models (GCMs) models and concluded that projected climate change was expected to result in a dramatic decrease in crop production countrywide. Another study by Gwimbi (2009) investigated the impact of climate change on cotton farming in Gokwe South district using cross-sectional analysis and found out that farmers were highly vulnerable to climate change as their annual yields were continuously decreasing as precipitation declines and temperatures increased across the district.

Nhemachena (2014) measured the economic impacts of climate change on agriculture in Zimbabwe based on a cross-section survey of over 700 farming households. The study employed the Ricardian approach to analyse the response of net revenue from crop and livestock agriculture across smallholder farming systems in the country to changes in climate normal (mean rainfall and temperature). The results show that net farm revenues are affected negatively by increases in temperature and positively by increases in precipitation. Farms with irrigation are more resistant to changes in climatic factors (high temperature and low rainfall), indicating that irrigation is an effective adaptation option to help reduce the impact of further changes in climate. The conclusion from the study was that dryland farming predominantly typical in Zimbabwe is the most vulnerable to high temperatures and low rainfall patterns, whereas the irrigated systems are the most tolerant.

An analysis of empirical studies reveals that the studies on the effects of climate variables on crop productivity have been considering single-crop analysis. The research is mainly concentrated on maize and cotton production. No research has quantified the effects of climate change on other key crops grown in Zimbabwe like soybeans, millet, sorghum, sugarcane and tobacco. To close this gap, this study includes eight crops: cotton; maize; millet; sorghum; soybeans; sugarcane; tobacco; and wheat. Quantification of the effects of climate variables on small grains like millet and sorghum have important policy implications for adaptation strategies for food security in the country in the face of climate shocks. In addition, measuring the effects of climate variables on tobacco (the leading export crop) is critical for export revenue implications of climate change.

Another limitation of empirical research done in Zimbabwe is that the studies only cover a shorter period or specific districts in Zimbabwe using cross-sectional data, which might compromise applicability of policy recommendation. Thus, no research has employed the time series data and Ricardian approach with the technique of error correction models. To address this lacuna, this study estimated the effects of climate variables on the eight selected crops using a Ricardian model with error correction modelling technique for a longer period from 1961 to 2016.

Climate change is a continuous phenomenon, which requires continuous and consistent analysis of its effects on various sectors of the economy, including agriculture. This implies that the studies on climate change and crop productivity nexus should also follow a continuity nature. However, the studies that were conducted on Zimbabwe were done up to 2014, thus the passage of time also warrants an investigation to see if there are any possible changes brought by the climate changes on crop productivity.

METHODOLOGY

The effects of climate change on agricultural productivity have been explored using the Ricardian model, which include regressing land values on climate change and other socio-economic control variables (Mendelsohn, Nordhaus, & Shaw, 1994). The approach reflects the costs and benefits of the implicit costs of the farmer's different adaptation strategies. In particular, the approach incorporates the substitution of various farm inputs and the invention of different activities that an individual farmer has adopted under existing climatic conditions (Kurukulasuriya & Mendelson, 2008). However, the method does not account for variation in prices and fully fail to control for the effects of other socio-economic variables that influence farm incomes (Mendelsohn and Dinar, 1999).

Theoretical Framework of the Ricardian Model

Given that the proposed study intends to investigate three agricultural crops separately, the approach proposed will, therefore, draw heavily on the conceptual contributions and empirical application of Deressa, Hassan, & Poonyth (2005). The econometric approach is based also on the Ricardian method to assess economic impacts of climatic changes, which allows for capturing adaptations farmers make in response to climate changes. The model is based on a set of well- behaved production functions of the form:

$$Q_i = (K_j, E) \quad (1)$$

Where Q_i is the quantity produced of good i, K_j is a vector of production inputs j used to produce Q_i and E defines a vector of exogenous environmental factors such as temperature, precipitation, and soil, characterizing production sites.

Given a set of factor prices w_j, E and Q, cost minimization gives the cost function:

$$C_i = C_i(Q_i, W, E) \quad (2)$$

Where C_i is the cost of production of good *i* and W (w_1, w_2...wn) is the vector of factor prices. Using the cost function C_i at given market prices, profit maximization by farmers on a given site can be specified as:

$$Max\pi = \left[P_i Q_i - C_i(Q_i, W, E) - P_L L_i\right] \quad (3)$$

Where P_L is annual cost or rent of land at that site, such that under perfect competition all profits in excess of normal returns to all factors (rents) are driven to zero

$$P_i Q_i^* - C_i^* = (Q_i^*, W, E) - P_L L_i^* = 0 \quad (4)$$

If the production of good *i* is the best use of the land given E, the observed market rent on the land will be equal to the annual net profits from the production of the good. Solving for P_L from the above equation gives land rent per hectare to be equal to net revenue per hectare.

$$P_L = (P_i Q_i^* \square C_i(Q_i^*, W, E) \ / L_i \quad (5)$$

The present value of the stream of current and future revenues gives the land value.

$$V_L = \int_0^\infty P_L e^{-rt} dt = \int_0^\infty [(P_i Q_i^* - C_i(Q^*, W, E) / L_i] e^{-rt} dt \quad (6)$$

The issue to be analyzed is the impact of exogenous changes in environmental variables on net economic welfare (ΔW). The net economic welfare is the change in welfare induced or caused by the changing environment from a given state to the other. Economic welfare change is measured in terms of change in the capitalized value of the land or alternatively in net farm income. Consider an environmental change from the environmental state A to B, which causes environmental inputs to change from EA to EB. The change in annual welfare from this environmental change is given by:

$$\Delta W = W(E_B - W(E_A) = \int_0^{Q_B} [(P_i Q_i - C_i(Q_i, W, E_B) / L_i] e^{-rt} dQ - \int_0^{Q_A} [(P_i Q_i - C_i(Q_i, W, E_A) / L_i] e^{-rt} dQ \quad (7)$$

If market prices do not change as a result of the change in E, then the above equation reduces to:

$$\Delta W = W(E_B) - W(E_A) = \left[PQ_B - \sum_{i=1}^{n} C_i(Q_i, W, E_B) \right] - \left[PQ_A - \sum_{i=1}^{n} C_i(Q_i, W, E_A) \right] \quad (8)$$

Substituting for PLL = PiQi* - Ci (Qi*, W, E) from (5)

$$\Delta W = W(E_B) - W(E_A) = \sum_{i=1}^{n} P_{LB} L_{Bi} - P_{LA} L_{Ai}) \quad (9)$$

Where P_{LA} and L_A are at EA and P_{LB} and L_B are at EB. The present value of welfare change is thus:

$$\int_0^{Q_B} \Delta W e^{-rt} dt = \sum_{i=1}^{n} V_{LB} LB_{Bi} - V_{LA} L_{Ai}) \quad (10)$$

The Ricardian model takes either (9) or (10) depending on whether data are available on annual net revenues or capitalized net revenues (land values VL). According to Deressa, Hassan, & Poonyth (2005), this model accounts for the direct impact on yields of different crops as well as the indirect substitution among different inputs including different activities, and other potential adaptations to different climate by measuring farm revenues.

Model Specification

Following the works of Deressa, Hassan & Poonyth (2005) and Kurukulasuriya & Mendelson (2008), the Ricardian model be specified as follows:

$$NR = \beta_0 + \sum_{i=1}^{5} \phi_i G_i + \beta_7 R + \delta_j R^2 + \lambda_J T + \alpha_J T^2 + \delta_t \quad (11)$$

Where *NR* is crop yield per hectare measured in hectograms[1] per hectare (hg/ha), while G is a vector of socio-economic variables. G_1 is crop land in hectares, G_2 is share of irrigated land in total agriculture land, G_3 is fertiliser usage per hectare, G_4 is agriculture machinery (tractors in use), G_5 is the agricultural population. *R* and *T* represent rainfall and temperature respectively. Since annual temperature and rainfall does not fully reflect the impacts of climate on crop productivity, we used deviation from normal temperature and rainfall as climate variables. The study extracted data for temperature and rainfall from Zimbabwe Meteorological Services Department; data for different crops were obtained from Food and Agriculture Organisation (FAO), and socio-economic variables data came from World Bank's World Development Indicators (WDI).

In equation (1), the linear terms indicate the unidirectional effects of the regressors on net crop revenue, whereas the quadratic or non-linear terms indicate the non-linear of net crop yield of the climate response function. The net crop yield function is doom-shaped when the coefficient of the quadratic function is negative suggesting a maximum point. On the other hand, net crop yield function is U-shaped when the quadratic term is positive indicating the minimum point.

Marginal values of climate variables are calculated to evaluate the marginal effects of climate shocks; however, these marginal values depend on the regression model used and climate variables under evaluation. In our regressions, the coefficients are the same as marginal values. The predictable marginal effect of a particular climate variable f on crop yield per hectare evaluated at the mean is given by:

$$E[dV / df_i] = b_{1,i} + 2^* b_{2,i}{}^* E[f_i] \quad (12)$$

Where f_i in this study represent climate variables; rainfall and temperature.

Empirical Model
Stationarity tests using the Augmented Dickey-Fuller indicated that all variables, except for sorghum and soybeans, became stationary in their first difference. Besides, Johansen cointegration test results have established that there is series cointegration. Therefore, the Ricardian model was estimated using the error correction technique. The error correction model was specified as follows:

$$D(NR_{pt}) = \alpha_0 + \alpha_1 D(G_{1t}) + \alpha_2 D(G_{2t}) + \alpha_3 D(G_{3t}) + \alpha_4 D(G_{4t}) + \alpha_5 D(G_{5t}) + \alpha_6 D(T_t)$$
$$+ \alpha_7 D(T_t^{\,2}) + \alpha_8 D(R_t) + \alpha_9 D(R_t^{\,2}) + \phi ECM_{t-1} + \omega_t \quad (13)$$

Where *D* is the first difference operator: $D(X_t) = X_t - X_{t-1}$. ECM_{t-1} is the error correction term (lagged residuals of the static equation).

EMPIRICAL ANALYSIS

Stationarity and cointegration tests

The empirical analysis started with unit root tests to determine whether the variables are stationarity of variables and appropriateness of the model specified. The employed the ADF-test to conduct stationarity tests. If the p-values are less than 5% it means that null hypothesis is rejected and the series does not have a unit root or is stationary. The stationarity test results are presented in Table 1below. The results

1 It is important to note that 1 Hectogram = 0.0001 Ton (Metrics).

of the ADF-tests for unit root or stationarity reveal that the variables are non-stationary in levels except for sorghum and soybeans. The non-stationary variables become stationary after their first differencing, that is, they are integrated of order one [I(1)].

Table 1: Unit root test results

Variable	Levels	1st Difference	Order of Integration
Cotton	-0.928	-9.573***	I(1)
Maize	-0.658	-4.539***	I(1)
Millet	-1.278	-3.226***	I(1)
Sorghum	-4.447***		I(0)
Soybeans	-4.949***		I(0)
Sugarcane	-1.671	-9.842***	I(1)
Tobacco	-1.295	-13.367***	I(1)
Wheat	-7.747	-7.440***	I(1)
Rainfall deviations	-2.238	-4.286***	I(1)
Temperature deviations	-1.522	-9.059***	I(1)
Crop land	-1.820	-9.387***	I(1)
Share of Irrigation Land	-2.094	-7.915***	I(1)
Fertiliser use per hectare	-1.631	-7.340***	I(1)
Agriculture Population	-2.040	-12.970***	I(1)
Agriculture Machinery	-1.396	-4.433***	I(1)

Note: ***; **; * respectively represents 1%; 5%; and 10% level of significance.

Since the majority variables are integrated of order one [I(1)], there is a possibility of cointegration or long-run relationship among variables. To test for the long-run relationship or cointegration, the study used Johansen Maximum Likelihood Approach – trace test. The null hypothesis for the trace test is that the number of vectors $r = r^* < k$, and the alternative is that $r = k$. Testing is done successively for $r^* = 1$; 2; 3; ….. and the initial rejection of the null hypothesis is taken as an estimate of r. The results are presented in Table 2 below.

Table 2: Results for Cointegration tests

Rank	Trace Statistic for a model							
	Cotton	Maize	Millet	Sorghum	Soybeans	Sugarcane	Tobacco	Wheat
r=0	431.3*	421.7*	425.9*	419.3*	423.3*	402.2*	428.9*	426.1*
r≤1	336.1*	322.5*	341.3*	328.5*	336.3*	319.6*	327.5*	337.6*
r≤2	267.2*	249.4*	263.9*	256.9*	252.6*	244.6*	253.2*	262.2*
r≤3	210.2*	195.3*	203.5*	194.1*	197.6*	186.1*	197.2*	198.4*
r≤4	156.1*	142.4*	149.8*	138.7*	145.6*	133.2*	145.3*	137.6*
r≤5	108.9*	99.2*	101.7*	99.8*	105.3*	93.0	104.1*	98.6*
r≤6	69.1	68.7	67.3	63.2	69.2	64.5	67.7	61.4
r≤7	38.4	41.3	39.8	39.0	41.0	40.4	39.1	34.4
r≤8	22.9	23.8	22.5	22.3	23.0	23.8	21.8	17.5
r≤9	9.64	11.6	10.3	12.4	10.6	10.2	10.2	6.63

Note: * denotes 5% level of significance

Cointegration analysis results (trace statistic) shows that there exist cointegrating vectors among the variables. The existence of cointegrating vectors implies that there is long-run relationship between crop yield, climate change and socio-economic variables. Akintunde, Okoruwa & Adeotu (2013) note that the existence of cointegration eliminates spurious correlation and the error correction is suggested. Hence, the error correction technique was adopted in this study.

Results for Error Correction Model

Following stationarity tests and Johansen cointegration analysis to establish the long-run relationship, we estimated the error correction model for all the selected crops. Table 3 shows the results of the error correction model.

The results of the error correction in Table 3 reveal that all the regression models do not suffer from misspecification, thus the F-statistics also shows that the models are corrected specified. The coefficients of determination (R-squared) exhibited goodness of fit for all models, thus more than 50% of the variations in each crop's yield per hectare are explained by climate and socio-economic variables.

The error correction parameter has an expected negative sign and significant for all models, suggesting that there is an error correction mechanism. This indicates that the long-run imbalances between crop yield, cropland, the share of irrigated land, fertiliser use, agriculture machinery, agriculture population, temperature and rainfall have the same evolution. In addition, the significant negative coefficient of the error correction term shows that the long-run equilibrium will be lower than the current yield and the rate at which differences between current and long-run yield will be corrected in future.

Table 3: Results for error correction model (ECM)

	Cotton	Maize	Millet	Sorghum	Soybean	Sugarcane	Tobacco	
Constant	-208.90 (-0.24)	-369.58 (0.29)	50.20 (0.10)	526.22 (1.03)	-1657.8 (-0.88)	-5545.5 (-1.20)	377.57 (0.29)	
Cropland	1.38 (0.39)	-10.62** (2.01)	-0.31 (-0.16)	-3.44* (-1.66)	-9.08 (-1.21)	-57.26 (-0.31)	-9.52* (-1.77)	8.33 (1.01)
Irrigated land	-81.21 (-1.25)	183.8** (1.94)	-41.04 (-1.11)	-36.86 (-0.96)	216.05* (1.56)	4161.3 (1.21)	237.9** (2.24)	
Fertiliser	0.02*** (1.66)	0.00 (-0.29)	0.01 (1.47)	0.00 (-0.49)	0.02 (0.78)	0.02 (0.05)	0.01* (0.78)	
Machinery	-0.11 (-0.71)	-0.27 (-1.18)	0.00 (0.00)	0.08 (0.91)	-0.14 (-0.42)	-1.66 (-0.20)	0.12** (0.48)	
Agriculture Population	549.33 (0.42)	723.29 (0.37)	38.98 (0.05)	-566.27 (-0.73)	2800.2 (0.97)	78187.9 (1.11)	-1050.2 (-0.52)	
Rainfall	52.17*** (4.79)	46.16*** (2.80)	9.29 (1.48)	31.82* (4.81)	-3.28 (-0.14)	-1739.8*** (-2.91)	15.72 (0.92)	
Rainfall squared	-0.04** (-4.34)	-0.02* (-1.87)	-0.01 (-1.09)	-0.02*** (-4.27)	0.00 (0.27)	1.27*** (2.84)	-0.01 (-0.65)	0.01 (0.41)
Temperature	-893.1** (-1.22)	-3675.6*** (-3.31)	216.8* (0.53)	-275.4*** (-2.96)	-774.1 (-0.48)	18802.7 (0.48)	4101.6*** (3.54)	
Temperature squared	8.83 (0.01)	175.49** (0.20)	-338.07 (-0.99)	71.26* (0.20)	1215.7 (0.92)	-48693.8 (-1.48)	-1837.1* (-1.92)	
ECM(-1)	-0.84*** (5.78)	-0.62*** (4.55)	-0.90*** (-5.74)	-0.64*** (-4.39)	-0.76*** (-5.20)	-1.12*** (-7.77)	-0.93*** (-6.03)	
N	55	55	55	55	55	55	55	55
R-squared	0.69	0.78	0.61	0.70	0.53	0.65	0.55	0.56
F-stat	9.90	15.53	6.99	10.27	3.66	8.10	5.29	4.55
Prob F-stat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05

Note: ***; **; * denotes 1%; 5%; 10% level of significance respectively.

The coefficient of crop land is negative and significant for maize, which means that as land used for crop production increases farmers attain lower yields from these crops. This finding corroborates the hypothesis in literature of an inverse relationship between land size and crop yield. The inverse relationship between land size and crop yield could be attributed to omitted variables such as soil quality (Matchaya, 2009). The results show that irrigation positively influences yields of maize, soybeans, sugarcane, tobacco and wheat. The policy message from this finding is that irrigation could provide an important channel of adaptation strategy and help farmer to improve crop yields per hectare, particularly the smallholder farmers suffering from changing climatic factors.

Even though fertiliser is one of the key determinants of crop yields, the findings indicate that fertiliser usage only improves cotton, tobacco and wheat yields. This could be true because application rates of fertiliser in Zimbabwe are very low. Also, it can be argued that while the use of fertilisers enhances crop production, it also increases content of greenhouse gases in the atmosphere causing global warming. Sarker, Alam & Gow (2012) noted that addressing climate change problems require reduced use of chemical fertiliser and increased use of organic manure in crop agriculture. The use of agricultural machinery such as tractors is associated with increased yields in tobacco and wheat farming.

Results show that rainfall has a positive and significant effect on cotton, maize and sorghum. A decrease in rainfall by 1mm would reduce cotton, maize and sorghum yields by 52.17, 46.17 and 31.82 hectograms, respectively. The negative and significant quadratic terms for cotton, maize, sorghum and soybeans mean that excess rainfall could result in yield reduction. It is quite reasonable to contemplate that excess rainfall could result in reduced yields due to nutrients leaching and flooding.

The temperature has a significant negative effect on cotton, maize and sorghum while the impact is positive for millet and tobacco. An increase in temperature by 1 degree would reduce yield per hectare of cotton maize and sorghum by 893, 3676 and 275 hectograms, respectively. The positive and significant quadratic terms for cotton and maize indicate that very low temperatures would result in yield reduction. The negative and significant quadratic terms for tobacco indicate that excess temperatures would be detrimental to tobacco production.

Our findings show that climate has a non-linear relationship with cotton, maize, millet, sorghum, soybeans and tobacco yields, which corroborates other findings (Nhemachena, 2014; Ochieng, Kirimi & Mathenge, 2016). In addition, the results reveal that the estimated coefficients of rainfall are lower than those of temperature, thus changes in temperature have a higher impact on crop productivity compared to changes in rainfall. This is consistent with the previous findings which show that temperature contributes more to the impact of climate change than rainfall, therefore, the temperature is an important climate factor for Zimbabwean crop yields in future (Mano and Nhemachena, 2009; Nhemachena, 2014). It is also evident from the findings that cotton, maize and sorghum are more sensitive to climate shocks, while millet and sugarcane are the least sensitive.

CONCLUSION AND POLICY RECOMMENDATIONS

This paper analyses the effects of climate change on eight selected crops (cotton, maize, millet, sorghum, soybeans, sugarcane, tobacco and wheat) for the period 1961 to 2016, using the time series Ricardian approach. Our empirical findings indicated that climate variables (rainfall and temperature) significantly affect crop yields per hectare in Zimbabwe. Crop yields per hectare are negatively affected by increases in temperature and decreases in rainfall. Although an increase in temperature reduces yields for cotton and maize, very low temperatures could also contribute to yield reduction. Tobacco is positively influenced by increasing temperature, but to a certain point. The decrease in rainfall reduces cotton, maize and sorghum yield per hectare. It can also be concluded that cotton and maize are the most sensitive crops, which respond to both rainfall and temperature changes. The results indicate that marginal increases in average temperature beyond optimum levels would result in decreased yield per hectare while the increase in rainfall to optimum levels would also boost productivity in Zimbabwe. Among the socio-economic variables, irrigation positively influences yields for crops like maize, soybeans, sugarcane, tobacco and wheat.

The results of this study are important for policies that aim to increase crop yields. The positive sign for irrigation in maize, tobacco and wheat underscored the importance of irrigation as a strategy to mitigate the negative effects of climate change on Zimbabwe's crop agriculture. Establishments of irrigation systems would effectively increase crop outputs. Growing of small grains like millet, which is less sensitive to climate shocks could also help smallholder farmers to deal with the harmful effects of climate change. This would also improve the food security of the country. Another mitigation strategy would be to promote agricultural research to increase crop varieties and to promote crop-soil matching to increase yields.

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CHAPTER **03**

CAPTIVITY TO TRADITIONAL PRODUCTION TECHNOLOGIES AND ITS IMPACT ON VULNERABILITY TO CONSUMPTION SHORTFALL DURING A DROUGHT SHOCK : EVIDENCE FROM SMALLHOLDER FARMERS IN HURUNGWE, ZIMBABWE

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ABSTRACT

Research on vulnerability of smallholder farmers to drought risk has recently attracted increasing attention due to climate-change. In this regard, this study used data from 411 randomly selected smallholder farmers from the Hurungwe District to estimate the impact of "captivity" to traditional production technologies on the vulnerability of farmers to consumption shortfall during a drought shock. The study first applied treatment effects technique to estimate the degree of captivity for each farmer and then used this imputed variable as one of the explanatory variables in a vulnerability regression model. In addition to imputing the degree of captivity for each farmer, the model also shows factors that influence the degree of captivity. The study then estimated vulnerability to consumption shortfall Probit model. Findings point to a high degree of smallholder farmers' captivity to traditional technologies caused by insufficient exposure, lack of education and training, lack of access to credit markets, low incomes and negative perceptions about modern technologies. Study findings further demonstrate that the smallholder farmers trapped in traditional production technologies have a higher probability of falling into consumption shortfall during a drought shock. Inefficiency, poverty, increased drought frequencies and gender, especially being female, also increase smallholder farmers' vulnerability to the risk of consumption shortfall during a drought shock. The main policy implications of the findings are that vulnerability can be significantly reduced through developing strategies and policies that promote adoption of new technologies by smallholder farmers, climate smart agriculture and gender-sensitive interventions in drought relief, subsidies and taxes.

***Key words**: Climate-change, Communal farmers, Food security, Technology enclavism*

INTRODUCTION

The mounting public consciousness of the subject of climate-change has generated vast concerns in developing countries regarding the potential impact of extreme weather events such as droughts and floods. Drought impact is, however, more interesting in Zimbabwe since drought has been the most frequent extreme weather event in the country (Meteorological Services Department, 2012). During past droughts, Zimbabwe responded to this climatic extreme by implementing *ad hoc* emergency food aid programs (World Food Programme, 2019 and Makaudze & Miranda, 2009). While food aid addresses consumption shortfalls during droughts in developing countries, it is costly and has the potential to cultivate a culture of the dependency syndrome. According to Kwemo (2017) and Heal & Lin (1998), the costs of government-administered food aid programs have been outrageous, sometimes reaching 10 % of the country's annual Gross Domestic Product (GDP), particularly during severe droughts. Dreze & Sen (1989) further contend that food aid partly addresses the problem of transitory household food insecurity but does not provide a permanent solution. Hence, increased drought frequencies are a threat, not only to smallholder farmers but also to the government in terms of budgetary pressures and derailing developmental targets.

Hoddinott, (2006) and Kinsey *et al*., (1998) note that in smallholder farming communities like Hurungwe District, smallholder farmers continue to be vulnerable to droughts. Tracing statistical data from the Grain Marketing Board (GMB) shows that these smallholder farmers are growing the same traditional cereal crops that were grown by their forefathers (GMB, 2016). Inheritance of forefathers' cropping systems in a changing climate by smallholder farmers in Hurungwe District raises an issue about the farmers' captivity to their forefathers' production systems. The inheritance could either be a result of the captivity[2] to traditional technologies or awareness (Egeru, 2012 and Nakashima *et al*., 2012) that traditional production methods can reduce the detrimental effects of climate-change or increased drought frequencies. What is disturbing, however, is the inappropriate attention given to the inheritance variable in the traditional production function. There are no clear mitigation strategies in the district; hence smallholder farmers remain vulnerable to ex-

2 Captivity to traditional production systems refers to farmers' difficulties or inability to move out of their parents' and forefathers' production systems or what can be referred to as traditional enclavism. It also implies the opposite of adopting modern technologies. In this case, if the probability of adopting modern technologies by a farmer is then that of the farmer's captivity to tradition is **1-θ.**

treme weather events. Vulnerability assessment is therefore crucial as it enhances farmers' ability to cope with extreme weather events.

Besides, the country has been struggling to meet its first sustainable development goal (SDG) number 1 of poverty reduction, particularly in rural communities where poverty levels remain too high (Malaba, 2013 and Manjengwa *et al.*, 2012) in an environment with increasing drought frequencies over the past decades (Meteorological Services Department, 2012 and Gwimbi, 2009). An assessment of weather-induced production and consumption shortfall vulnerabilities, therefore, enlightens the Government on the implications of increased drought frequencies on the country's SDG target of poverty elimination.

While modern technology is identified in many studies as an adaptation strategy which moderates smallholder farmers' harm from extreme weather events (IPCC, 2011 and Fafchamps, 2009), the link between access to technology and farmers' vulnerability to extreme weather events has remained a contentious area (Schultz, 1964). The role played by traditional and modern technologies in farmers' vulnerability to climate-change has therefore attracted interest in the field of economics and other social sciences. Recently, a number of researches applying different methods of assessment have been carried out in a number of developing countries and producing diverging conclusions. On one hand, many studies have identified improvements in agricultural technologies as the key to smoothen consumption in developing countries during drought periods (Oyekale & Oladele, 2012; Below *et al*., 2010; Kokate *et al*., 2010; Hassan & Nhemachena, 2008; Sarker *et al*., 2008; Adepetu & Berthe, 2007; Omolehin *et al*., 2007 and Wossink *et al*., 1995). The consensus among these studies is that the continuous use of traditional technologies in a changing climate will have a serious consequence on agricultural productivity and food security (Gwimbi, 2009; Gbetibouo, 2009; Mannak, 2009; Parry *et al*., 2009 and Hassan & Nhemachena, 2008). On the other hand, a number of studies argue that traditional technologies are key to reducing the vulnerability of farmers to extreme weather events (Egeru, 2012; Nakashima *et al*., 2012; Macchi *et al*., 2008; Nyong *et al*., 2007; Robinson & Hebert, 2001 and Hunn, 1993). Schultz's (1964) "poor but efficient" hypothesis buttresses that new technologies may reduce productivity especially in areas where farmers lack the willingness to adjust input levels due to familiarity to old technologies (Schultz, *Ibid*).

Literature further shows that although modernisation of agricultural technologies can be used to reduce smallholder farmers' vulnerability to drought risks, the smallholder farmers may also be coerced to adopt these modern technologies by increased drought frequencies (Uddin *et al*., 2014;

Wang *et al*., 2010; Deschenes & Greenstone, 2007). Consumption shortfall in a given drought year

may force smallholder farmers to modernise their technologies in preparation for future similar risks. This implies that the technology adoption variable is endogenously determined. Smallholder farmers do not willingly choose to remain in traditional captivity or to move out of traditional captivity. For instance, smallholder farmers in Africa have continued to lag behind modern technologies and even the Green Revolution failed to benefit them (Gollin *et al*., 2005; Zimmerman & Carter, 2003). This suggests a vital research issue that has to be investigated in line with the measurement of the technology variable. The question involves identifying factors inhibiting African smallholder farmers in adopting modern technologies.

The main objective of the study was therefore to examine the impact of captivity to tradition or the impact of modern technology on smallholder farmers' vulnerability to consumption shortfall during a drought shock in Hurungwe District of Zimbabwe. However, since captivity to traditional technologies is not exogenously determined, the study first estimated smallholder farmers' degree of captivity to traditional technologies and then applied the estimated captivity variable in investigating the impact of captivity to traditional technologies on smallholder farmers' vulnerability to consumption shortfall during a drought shock. In this view, the study attempted to answer the following questions:

1. What determines smallholder farmers' captivity to traditional production methods or what factors explain modern technology adoption by smallholder farmers? Hence, what is the degree of each farmer's captivity to tradition? and
2. What is the impact of smallholder farmers' captivity to tradition on consumption shortfall during a drought shock?

Maize was selected in this study because it is Zimbabwe's primary staple food crop and is therefore at the heart of food security and consumption status in the country. The larger proportion of maize output produced by farmers in Hurungwe District is for consumption. Farmers' consumption levels heavily depend on what they produce (Chauvin *et al*., 2012).

THEORETICAL FRAMEWORK, MEASUREMENT OF VULNERABILITY AND CAPTIVITY

The measurement of household vulnerability to natural hazards has been a problematic area in research. Only recently have a number of researchers started to construct an index for vulnerability. For instance, White *et al*. (2005) and Adger *et al*. (2011) computed the vulnerability index () as a product of exposure () and susceptibility () divided by coping capacity (), that is:

$$V=(E*S)/CC \qquad (1)$$

where E is exposure, S is susceptibility and CC is coping capacity. The index presented in equation (1) is a composite measure comprising of several indicators (social, economic, political, ecological and physical). These indicators are, however, subjectively selected by researchers (Brooks *et al*., 2005). Socio-economic indicators that have been widely used in vulnerability index include poverty, per capita consumption and income, productivity and unemployment, among others (IPCC, 2014; Hinkel, 2011 and Taubenbock *et al*., 2008). Coping capacity (CC) include indicators such as the state of technology (IPCC, 2012; IPCC, 2014 and White *et al*., 2005) and others. The relationship between technology adoption and farmers' vulnerability is clear in equation (1). Since technology is an indicator of coping capacity, any form of technology that increases CC will reduce vulnerability to extreme weather events.

The main disadvantage of using the vulnerability index in (1) is its composite nature and the subjectivity of the selection of indicators. For instance, if extreme weather increases the index by 10% then this will be the only information available to policy- makers. Policy-makers require information about the impact of these events on some specific indicators such as poverty, consumption and productivity. It is in this regard that this study decomposed the index and made use of specific indicators. The choice of consumption indicator was driven by the need to advise the government about the implications of increased drought frequencies on Sustainable Development Goals (SDGs) targets. Hinkel (2011) argues that vulnerability assessments help in identifying mitigation targets for vulnerable farmers to allocate adaptation funds, raising awareness about extreme weather patterns and monitoring adaptation and mitigation policies. Decomposing the vulnerability index into specific indicators such as assessment of vulnerability to consumption shortfall will provide recommendations directly linked to the goal of food security in both national goals and United Nations' SDGs.

Taubenbock *et al*. (2008) and IPCC (2012) provide a hierarchical holistic framework conceptualising extreme weather patterns, vulnerability and risk with a selection of measurable indicators. Table 1 presents a variety of indicators for different categories of vulnerability. This study applied indicators for economic vulnerability because the study's ultimate goal was to inform economic policies.

Table 1: Hierarchical Holistic Vulnerability Framework with Indicators

<table>
<tr><th colspan="2"></th><th></th><th>Components</th><th>Indicators</th></tr>
<tr><td rowspan="7">Risk</td><td rowspan="2">Hazard</td><td></td><td>Natural hazard, human threat, phenomenon</td><td>Magnitude, intensity, spatial exposure, probability of occurrence, duration, time.</td></tr>
<tr><td></td><td>Secondary threats, after effects</td><td>Height, slope, orientation, soil type, etc.</td></tr>
<tr><td rowspan="5">Vulnerability</td><td rowspan="5">V=(E*S)/CC</td><td>Political vulnerability</td><td>Political system, willingness, early warning systems, crisis and information management, etc.</td></tr>
<tr><td>Demographic vulnerability</td><td>Total population, population density distribution, etc.</td></tr>
<tr><td>Social vulnerability</td><td>Education, public awareness, health, social network, gender, etc.</td></tr>
<tr><td>Economic vulnerability</td><td>Poverty, income, consumption, productivity, unemployment rate, etc.</td></tr>
<tr><td>Physical vulnerability/ Ecological vulnerability</td><td>Infrastructure quality, natural resources availability, forestry, etc.</td></tr>
</table>

Source: Taubenbock et al. (2008)

The other weakness of the vulnerability framework presented in Table 1 is its inability to account for endogeneity of technology adoption where increased drought frequencies may drive farmers to adopt new technologies or modern technologies may affect farmers' vulnerability to drought risk. The presence of endogeneity implies that a robust estimation of the vulnerability model is crucial. It is against this background that the instrumented technological adoption (captivity to traditional production methods) was used in the vulnerability model. In other words, the study first generated an instrument for captivity to tradition and then assessed how this instrument affects farmers' vulnerability to consumption shortfall. While vulnerability literature identifies economic variables such as poverty, per capita income, consumption levels, output, inflation and unemployment, among others, as indicators for farmers' vulnerability (Taubenbock *et al*., 2008; Fussel, 2007 and Turner *et al*., 2003), in this study consumption shortfall was selected as an indicator of vulnerability. The micro nature of this measure makes it more appropriate for a micro-study. Other indicators such as unemployment and inflation are macro-level and can only be used in macro studies.

Besides the convergence hypothesis theory which attempts to relate current economic growth to lagged economic growth, there has been a subdued attempt in economics to theoretically link inheritance with production and consumption. As a result, this study suggests a framework derived from the Cobb-Douglas production function. The framework developed in this study is based on the following assumptions:

1. Farmers in Hurungwe District are rational: farmers can only change to a new technology if they perceive it to produce larger output. This assumption has an implication that improvement in technology is perceived to produce larger output than traditional technologies. The assumption may, however, not hold under uncertainty where the choice of the farmer may not only be the average output;

2. Freedom of choice: farmers are free to choose any affordable technology they want, traditional or modern; and

3. Majority of smallholder maize farmers are subsistence-driven.

It is in this regard, that the study analysed the production function with artificial inputs and deduced drought hazard vulnerability differentials between two groups of farmers; those using traditional technologies and those using modern technologies. A modified Cobb-Douglas production function with constant returns to scale was applied. The choice of this particular function was mainly based on Kaldor (1961) who established that the shares of income accruing to capital and labour remain constant over time, hence the suitability of constant returns to scale. The general Cobb-Douglas production function takes the following form:

$$Q_{it}=A_{it} K_{it}^{(1-\alpha)} L_{it}^{\alpha}, \text{ for } t=1 \quad (2)$$

where is the output of the farmer in time *t* or the farmer's consumption level in a subsistence scenario, and are capital and labour of the farmer in time *t*, respectively, is the input productivity, that is, the productivity of labour and capital, is the %age of output going to workers and is the %age of output going to the owners of capital. Input productivity is a function of the technologies used and labour quality. In this Cobb-Douglas production function, current output produced is a function of current technologies. This type of relationship applies to all other types of production functions. Hence, this modification can also apply to any other type of a production function. In the modification, current output produced is considered as a function of both modern technologies and traditional technologies. The right hand side of the Cobb-Douglas function is retained as it is in equation (2) but with a slight modification in order to accommodate the influence of traditional captivity on current output of economies characterised by traditional sectors.

The production function is therefore expressed as:

$$Q_{it}=(A_{it} K_{it}^{(1-\alpha)} L_{it}^{\alpha})^{\theta} Q_{(it-s)}^{(1-\theta)} 1 \quad (3)$$

where captures traditional technologies and is the degree of response by farmers to modern technologies. Education influences labour quality hence its productivity is captured in . If then the current production is simply the inherited production level from period *t-s*. Based on equation (3), the first assumption and the modified Cobb-Douglas production function, it is clear that output growth is attained through increasing in the modern school of thought. The larger the value of , the more responsive is the output to technological changes and the larger is the output to be produced according to proponents of the modern school. In other words, it is the choice of that determines growth and the ability to develop new mitigation strategies to hedge against production/consumption deficiency during droughts. A combination of a large time lag or a large value of *s* and a small value of imply a non-growing output.

Droughts depreciate the quality of natural capital; hence the production function in equation (3) can be re-expressed as:

$$Q_{it}=(A_{it} K_{it}^{(1-\alpha)} L_{it}^{\alpha})^{\theta} Q_{(it-s)}^{(1-\theta)}-D_{it}^{\lambda} \quad (4)$$

where is the depreciation of natural capital owing to a drought shock which is assumed to be different across wards in the Hurungwe District and is the response of output to natural capital deterioration. By letting and representing modern and old technologies, respectively, equation (4) can be expressed as:

$$Q_{it}=N_{it}^{\theta} O_{it}^{(1-\theta)}-D_{it}^{\lambda} \ln(Q_{it})=\theta \ln(N_{it})+(1-\theta)\ln(O_{it})-\lambda\ln(D_{it}) \quad (5)$$

If is the minimum maize production that would put a subsistence smallholder farmer out of consumption deficit then for a farmer to be out of consumption deficit:

$$\theta \ln(N_{it})+(1-\theta)\ln(O_{it})-\lambda\ln(D_{it})\geq C^{*} \quad (6)$$

$$\theta \frac{dN_{it}}{N_{it}}+(1-\theta)\frac{dO_{it}}{O_{it}} \geq \lambda \frac{dD_{it}}{D_{it}} \quad (7)$$

where equation (7) is a total differential of equation (6).

The traditional school of thought is associated with a closer to zero and it is zero under extreme situations of no modern technology adoption by farmers. Under such cases, we derive the following condition from equation (7):

$$\frac{dO_{it}}{O_{it}} \geq \lambda \frac{dD_{it}}{D_{it}} \quad (8)$$

Traditional knowledge or traditional technology proponents argue that the condition in equation (8) always holds for poor African farmers if new technologies which are assumed to be destructive to the environment are not adopted. New technologies disturb poor farmers' ability to adapt or mitigate drought hazards but in the absence of technology adoption or with traditional knowledge, the average growth rate of smallholder farmers' output from the use of old technologies or traditional knowledge is always greater than the average growth rate of natural capital depreciation weighted by the response rate of output to natural capital depreciation.

However, the modern school argues that equation (8) cannot hold because the average growth rate of output from old technologies is always less than the average growth rate of natural capital depreciation in a changing climate. According to the modern school, farmers can only avoid being vulnerable to climate-change and extreme weather hazards through technological progress. The proponents of this school of thought advocate for a closer to one and one under extreme situations of a 100 % technology adoption. Equation (7) under a 100% technology adoption or under conditions with a equal to one provides the following condition for the modern school:

(dN_it)/N_it ≥λ (dD_it)/D_it (9)

The condition in (9) states that farmers can prevent extreme weather hazards as long as the average technology growth rate is at least greater than the average growth rate of natural capital depreciation weighted by the response rate of output to natural capital depreciation.

If farmers are captive to traditional technologies, that is, if they are rigid and resistant to changes in technology, then the level of output produced will be determined by the historical levels of output. In other words, if there is drought today similar to the one occurred in time *t-s* then the status of consumption today (deficit or enough) will be similar to or less than that experienced in period *t-s* for those tied to the traditional technologies. One of the hypotheses of the study is therefore that farmers who are tied to the traditional production systems, those who inherit their ancestors' production systems, are more likely to suffer from consumption deficits during drought periods if in fact they and their parents have a historical record of consumption deficits during the past droughts. The study hypothesises that the continued consumption deficits in the Hurungwe District during droughts is caused by farmers' captivity to traditional/ancestral technologies or farmers' inability to adopt new technologies. In general, the study tested and compared the vulnerability to drought consumption shortfalls of farmers using old technologies with those using modern technologies.
While one of the study's aims is to compare farmers with different s, the measurement of is one aspect considered in this study. The values of are not exogenously given but they are also endogenous. In most cases, farmers do not willingly decide to use old methods of production () but they are sometimes constrained by some factors which explain the reasons for their captivity to traditional technologies. In this view, the study constructs a variable representing the decision to use as a function of some explanatory variables defined in the innovation-diffusion, adoption perception and economic constraints models. In these models, the probability that a farmer decides to use old technologies or decides to adopt new technologies is explained by farm size, perception towards the effects of new technology, access to information, farmer's resource base, access to extension services, access to credit, education, religion, farmer's experience, and human values such as farmer's beliefs. The predicted probabilities generated from this technology adoption model are subtracted from 100 % to provide a new continuous variable representing captivity to traditional technologies.

Captivity to traditional production systems refers to farmers' difficulties or inability to move out of their parents' and forefathers' production systems or what can be referred to as traditional enclavism. It also implies the opposite of adopting modern technologies. In this case, if the probability of adopting modern technologies by a farmer is then that of the farmer's captivity to tradition is . Similarly, captivity can also be defined as the degree of flexibility to break away from what the farmer has inherited from the parents or used over the years. For this study, a farmer was said to have adopted new agricultural technology if he/she has adopted at least one of the following as an independent farmer: hybrid or improved seed variety, a tractor, a pump, a harvester, a planter, a generator, modern irrigation equipment and modern weather forecasting equipment, valued at least around US$500 over the past 10 years. The period of a decade was considered because investment decisions in agriculture are usually long term or medium term plans. The value of US$500 is US$50 per year. Based on information collected from the District, some farmers may get new seed varieties or chemicals as donations. However, most donations in the District are valued at a maximum of US$50 for receiving households. This was considered to be a minimum in order to exclude insignificant adoptions such as donations from relatives, and other institutions.

DATA AND ESTIMATION METHODS

The data used in this article was collected using a questionnaire from a sample of randomly selected 411 farmers from Hurungwe District. Hurungwe District was selected because of its unique features which are attractive to the study. Firstly, the district is characterised by both wet and dry regions which makes it an appropriate cross-sectional case for studying the impact of weather variability on farmers. Secondly, the district is one of the major grain producers in Zimbabwe, which makes it critical for policy issues in grain production and food security. Thirdly, the district is the second-largest in Zimbabwe. So, reducing vulnerability in the district will significantly improve the country's efforts to achieve SDGs. The main advantages of a case study are that: 1) the intensive description and analysis of a single district provides a good source of ideas about the behaviour of farmers, 2) a case study provides an opportunity to have an in-depth study of a given phenomenon, 3) case studies are flexible; they can introduce new and unexpected results and 4) it is more focused and therefore a powerful tool for analysing individual districts.

A multi-stage sample selection was done. First, wards were stratified according to ecological zones, and then one ward was randomly selected from each ecological zone (regions IIA, III and IV). Only ecological region V was disregarded because no significant agriculture is practised in the region, which is set aside for wildlife management. Each selected ward was proportionally represented in terms of the sampling units. Enumeration areas (EAs) within each ward were then randomly selected and a census was carried out within the selected EAs. Data from the Poverty, Income, Consumption and Expenditure Survey (PICES) produced by the Zimbabwe National Statistics Agency in 2011/2012, Census 2012 and Moving Zimbabwe Forward data set (collected in 2012 by the Institute of Environmental Studies of the University of Zimbabwe) was also used to compare general household characteristics such as education and household size. The data sets tally well, indicating a reasonable degree of reliability, which is also supported by Cronbach's Alpha of 78.4%. Potential outliers were eliminated from the data to avoid problems associated with measurement errors. In analysis STATA 15 was applied.

To examine the impact of captivity to traditional technology on farmers' vulnerability to consumption shortfall during a drought shock, a two-stage Probit technique was applied in this study. Since the main objective of this study was to assess the influence of traditional captivity on consumption status during droughts, the traditionally-captive variable was estimated first using a Probit model with treatment effects. The two-stage Probit procedure was applied as follows: First, a Probit model explaining the probability of technology adoption by farmers was formulated and estimated to provide predicted values of captivity to tradition. The main advantage of using the two-stage Probit approach is that it compensates for a large number of farmers who did not adopt modern technologies, thereby correcting for selection bias (Heckman, 1979).

However, the captivity variable was also estimated but using treatment effects. Foster and Rosenzweig (2010) argue that farmers can only adopt new technologies if they are aware of it. However, some farmers may not be aware when a new technology is introduced. As a result, the observed sample parameter may not be a consistent estimator for the true population parameter. Under such circumstances, applying the traditional classical models of adoption when the target population is not universally exposed to the new technology may result in non-exposure bias which produces biased and inconsistent estimators for population adoption rates since farmers' exposure to a new technology is non-random (Diagne & Demont, 2007 and Simtowe *et al*., 2011). It is against this background that this study measures the degree of captivity to tradition using a programme evaluation methodological approach, as in Wooldridge (2002).

In estimating the captivity variable, consider as indexing farmers and as a treatment indicator, equal to 1 if the farmer is exposed to agricultural technology and equal to 0 if the farmer is not exposed to agricultural technology. Farmers exposed to agricultural technology are referred to as the 'treated' while those not exposed to new technology are the 'untreated'. A farmer was said to have adopted new agricultural technology if he/she has adopted at least one of the following as an independent farmer: hybrid or improved seed variety, a tractor, a pump, a harvester, a planter, a generator, modern irrigation equipment and modern weather forecasting equipment, valued at least US$500 over the past 10 years. Additionally, consider and to be the potential adoption outcomes that would occur when a farmer is not treated (= 0) and when a farmer is treated (= 1), respectively. Either or is observable but not both. For example, we can only observe that a treated farmer has adopted agricultural technology but we cannot certainly deduce what would have been the outcome if this farmer was not exposed to the technology (Pindiriri, 2018). The inference is thus counterfactual, an adoption outcome that would have happened if the farmer was not exposed to technology. Dimara and Skuras (2003) call this the problem of missing data because the impact of exposure on the same farmer cannot be measured.

The farmer's agricultural technology adoption outcome is then given as:

$$\pi_i = E_i \pi_{i1} + (1 - E_i) \pi_{i0} \quad (10)$$

$$\pi_i = \pi_{i0} + (\pi_{i1} - \pi_{i0}) E_i = \alpha_i + \beta_i E_i \quad (11)$$

where = and = - are the intercept and the treatment effect for the farmer, respectively. Since only one of the components of is observable, the treatment effect is unidentified but we can identify useful measures such as the average treatment effect (*ATE*), the average adoption outcome of farmers exposed to technology (*ATET*) which averages over a sub-set of farmers exposed to technology and the average of the entire population of the farmer treatment effects of farmers not exposed to technology (*ATENT*) which averages over a sub-set of farmers not exposed to technology. The three measures of treatment effect are measured as:

$$ATE = E(\beta_i) = E(\pi_{i1} - \pi_{i0}) = \beta = E(\pi_1 - \pi_0) \quad (12)$$

$$ATET = E[\beta_i \,|\, E_i = 1] = E[(\pi_{i1} - \pi_{i0}) \,|\, E_i = 1] \quad (13)$$

$$ATENT = E[\beta_i \,|\, E_i = 0] = E[(\pi_{i1} - \pi_{i0}) \,|\, E_i = 0] \quad (14)$$

The population bias, the difference between *ATE* and *ATET*, was controlled in order to avoid biased and inconsistent estimators for *ATE* and *ATET* (see Wooldridge, 2002 and Diagne & Demont, 2007). Exposure to technology is a necessary condition for technology adoption, hence = 0 and *ATE* = *E*(). Variables used in this article and their definitions come from the reviewed literature. The dependent binary variable is agricultural technology adoption () by a farmer which takes a value of 1 if the farmer has adopted at least one of the following as an independent farmer: hybrid or improved seed variety, a tractor, a pump, a harvester, a planter, a generator, modern irrigation equipment and modern weather forecasting equipment, among others but with only a minimum value of US$500 over ten years and 0 otherwise. In addition to the wide definition of agricultural technology used in this article, a narrow definition which considers components of the broad definition such as modern weather forecasting, type of seed and fertilizer was also used. The endogenous variable, , is determined by a vector of covariates, ***X***. In summary, technology adoption and its drivers can be estimated from random vectors, (, ,) for *i* = 1... *n*. To estimate *ATE*, the treatment condition () is assumed to be independent of the possible adoption outcomes, $_0$ and $_1$. The population mean technology adoption conditional on vector ***X*** is given as:

$$ATE(X) = E[\pi 1 = 1 \,|\, X] \quad (15)$$

Using the parametric approach, the conditional independence assumption allows us to estimate technology adoption and its drivers from the treated sub-sample only through the following specification:

$$E[\pi \,|\, X, E = 1] = f(X, \lambda) \quad (16)$$

where *f* is an identified linear or non-linear function of a vector of explanatory variables and unknown parameter vector to be estimated. The estimated equation was then used to compute the predicted values which were then used to estimate the *ATE* and *ATET*[3] for the whole sample and treated sub-sample, respectively. The farmers' technology adoption gap (GAP)[4] is the magnitude of ATE from the joint exposure and adoption parameter (JEA). Literature identifies the factors in Table 2 as the main determinants of technology adoption by farmers.

Table 2: Determinants of technology adoption

Adoption determinants (X)	Expected sign
Exposure to technology (= 1 for exposed farmers) (*E*)	+
Age of the farmer in years (*Age*)	+/-
Farm size in hectares (*Fsize*)	+/-
Credit (=1 for access to credit)	+
Farmer's education in years of schooling (*Edu*)	+
Extension services in number of contact days (*Ext*)	+
Gender (=1 for male)	+
Belief (= 1 for traditional/ follower of forefathers)	-
Income in US dollars	+
Farming experience in years (*Exp*)	+
Weather (= 1 for wet)	+
Perception (=1 for positive perception)	+
Training (=1 for agricultural trained farmers)	+
Parent belief (1 if tradition)	-

The variables, age (in years), farm size (in hectares), extension services (number of contacts per year), income (dollars), farming experience (in years) and education (in completed years) are continuous while the rest were measured as categorical variables. Exposure takes a value of 1 for farmers exposed to technology and zero otherwise, same to access to credit, which takes a value of 1 for farmers with access to credit and zero otherwise; weather, which takes a value of 1 for wet weather and zero otherwise; training, which takes a value of 1 for trained farmers and zero otherwise; and gender, which takes a value of 1 for male farmers and zero otherwise. Farmers who believe in tradition take a value of 1 and zero otherwise and farmers who perceive modern technologies as better than traditional technologies take a value of 1 and zero otherwise. Parent belief takes a value of 1 if the farmer's parents are/were traditionalists and zero otherwise. Traditionalists are farmers who stick to the traditional methods of farming. The predicted values of the technology adoption determinants model give the values of or the degree of adoption. The opposite, , measures the degree of captivity.

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3 $A\hat{T}E = \frac{1}{n}\sum_{i=1}^{n} f(X_i, \hat{\lambda})$ and $A\hat{T}ET = \frac{1}{n_E}\sum_{i=1}^{n} E_i f(X_i, \hat{\lambda})$

4 $G\hat{A}P = J\hat{E}A - A\hat{T}E = \frac{1}{n}\sum_{i=1}^{n} \pi_i - \frac{1}{n}\sum_{i=1}^{n} f(X_i, \hat{\lambda})$

The second phase comprised of regressing consumption status or food adequacy during a drought shock (*FA*) on predicted values of traditional captivity and other control variables which include inefficiency, poverty, education, drought experience, weather forecasting techniques and extension services, among others. The applied model is:

$FA\_i=g(CapTr\_i,Z)+\varepsilon\_i$ (17)

where was consumption status or food adequacy of farmer during the 2013/14 drought year, is degree of captivity to tradition of farmer , is a vector is control variables which include technical efficiency farmer , the level of poverty of farmer , education, agricultural training, droughts encountered, gender, age, household size, weather forecasting techniques and extension services. is the error term which is assumed to be normally distributed with a mean of zero and constant variance. The dependent variable, food adequacy (), was measured as a dummy variable, taking a value of one if the farmer had adequate food or a food consumption score above the food poverty line during the 2013/14 drought year and zero otherwise. It is also referred to as food adequacy. is a measure of captivity to traditional production systems estimated as . Technical efficiency is a measure of technical efficiency estimated in Pindiriri *et al*. (2016) while poverty is a measure of poverty estimated in Pindiriri *et al*. (2015). Technical efficiency measures the proportion of what the farmer is actually producing given the available inputs relative to the maximum that can be produced by the same inputs. The rest of the other control variables were measured as explained in the technology adoption model.

The linear form of the model (17) in matrix notation is presented as:

$FA=X\delta+\varepsilon$ (18)

where is a vector of the dependent variable, is a vector of explanatory variables, is a vector of slope coefficients and is a vector of residuals. Since the dependent variable is dichotomous it makes no sense to think of a regression (18) as a conditional average. Averaging 0 and 1 provides a meaningless score and it is, therefore, important to consider the conditional average as the proportion of farmers saying they had enough/adequate food during the 2013/14 drought or the proportion of 1's among farmers sharing the value for the explanatory variable. It can generally be regarded as the conditional probability of sampling a 'yes' among farmers with regards to food adequacy. We can assume that,), the errors are uncorrelated and apply the ordinary least squares (OLS) technique to model (18). Applying OLS to model (18) gives a linear probability model (LPM). However, the LPM has serious shortcomings which include: failure to constrain probabilities between 0 and 1, failure to satisfy the assumptions of normality of error terms and homoscedasticity of the variance of error term and production of useless R-squared.

In order to guarantee that the probability stays between 0 and 1, a positive monotone function that maps the linear predictor, , into a unit interval was considered. A transformation of such nature maintains the linear nature of the regression function while preserving the probability rule that probability always stay between 0 and 1. This requirement can be met by any type of cumulative probability distribution function:

$\psi\_i=Pr(\tau\_i)=Pr(X\delta)$ (19)

where the cumulative distribution function (CDF), , can be pre-determined and vector is estimated. Assuming to be strictly increasing, model (19) can be expressed as:

$Pr^{(-1)} (\psi\_i)=\tau\_i=X\delta$ (20)

where is the inverse of the cumulative distribution function. The unit-normal distribution was used in this study, that is, the cumulative normal distribution, , was used to produce a linear probit model:

$\psi\_i=\Phi(X\delta)=1/\sqrt{2\pi} \int\_{(-\infty)}^{X\delta} e^{(-z^2/2)} dz$ (21)

where and z is a standard score placed on a normal distribution. Specifically, a two-step probit procedure was applied in this study.

FINDINGS AND DISCUSSION

Farmers' degree of captivity to tradition

The descriptive statistics illustrated in Table 3 show that a majority (76.9%) of the sampled farmers were males and only 19.7% of the farmers were not exposed to any agricultural technology never having been applied by their forefathers. Despite many farmers (80.3 %) having been exposed to agricultural technologies in the district, only 30.2 % of the 411 farmers adopted agricultural technologies that have never been used by their parents. The findings display significant differences between adopters and non-adopters in terms of their gender proportion, training, beliefs, credit access and exposure to technology, perceptions about modern technologies, knowledge sources, parents' beliefs, age, education and contact with extension officers, farming experience and incomes (see Table 3). The male to female ratio is bigger in the sub-sample of farmers who adopted agricultural technologies and smaller in non-adopters.

Table 3: Farmers' characteristics according to their adoption status

Characteristic	Non-adopters (N=287)	Adopters (N=124)	Total (N=411)	Difference
Proportion of male farmers (%)	72.3	87.1	76.9	-14.6***
Proportion of farmers in wet zones (%)	56.4	62.1	58.2	-5.7
Proportion of traditionalists (%)	62.0	35.5	54.0	26.5***
Proportion of formally trained farmers (%)	2.8	33.9	12.2	-31.1***
Proportion of farmers with credit access (%)	15.7	75.8	33.8	-60.1***
Farmers exposed to modern technology (%)	76.3	89.5	80.3	-13.2***
Farmers saying modern tech is better (%)	54.4	98.4	67.6	-44.0***
Farmers with traditional parents (%)	80.1	47.6	70.3	32.6***
Farmers with modern knowledge sources (%)	22.3	79.0	39.4	-56.7***
Average farm size (hectares)	8.76	8.7	8.74	0.1
Average age of farmers (years)	45.0	41.0	44.0	4.0***
Average education of farmers (years)	8.0	11.0	9.0	-3.0***
Average extension contacts (per year)	6.0	15.0	10.0	-9.0***
Average farming experience (years)	17.0	14.0	16.0	3.0**
Average yearly income (dollars)	1654	6407	3088	-4753***

***, ** and * indicate that the difference between adopters and non-adopters is statistically significant at 1, 5 and 10% level, respectively. Differences in proportions and means were tested using t-tests for equality of means and Levene's test for equality of variances.

The findings illustrated in Tables 4 and 5 show that the average treatment effect (ATE) is 42.9 %. Exposure to agricultural technologies causes adoption rates of these technologies to increase by an average of 42.9 % from an average of 3.2 % of farmers not exposed to technologies. The average treatment effect on the treated (ATET) is 33 %. Among the exposed farmers, awareness causes adoption rates to increase by an average of 33 % from the average of 0 % that would have occurred if the farmers had not been exposed to these technologies. Potential outcome (PO) averages indicate that the average rate of adoption for exposed farmers is 46 % while for non-exposed farmers is merely 3.2 %. The actual adoption rate is 30.2 % and the population adoption gap emanating from farmers' incomplete exposure to agricultural technologies is 12.7 %. There is potential to improve adoption rates of agricultural technologies by 12.7 % in Hurungwe District through the provision of information or making farmers aware of the existing technologies.

Table 4: Summary of adoption rates of agricultural technologies in Hurungwe

Adoption is the dependent variable			
Variable	Coefficient	PO means	Coefficient
ATE (exposure 1 vs 0)	0.429***	PO mean (exposure 0)	0.032***
ATET (exposure 1 vs 0)	0.330***	PO mean (exposure 0)	0.000
PO mean (exposure 1)	0.460***	PO mean (exposure 0)	0.032***

PO stands for potential outcome. ***, ** and * indicate that the coefficient is statistically significant at 1, 5 and 10 per cent level, respectively.

Table 5: Detailed statistics of technology adoption rates and adoption gap

Dependent variable (Adoption) Estimator	Coefficient	Std. Err	z-statistic	p-value
PO mean (exposure = 1)	0.460	0.025	18.3	0.000
ATE (potential adoption rate)	0.429	0.025	17.4	0.000
ATET (Adoption among exposed farmers)	0.330	0.027	12.2	0.000
JEA	0.302	0.025	12.1	0.000
GAP (Adoption gap)	-0.127	0.036	-3.53	0.000
Population selection bias	0.099	0.021	4.71	0.000

The huge technological gap in the district or the high level of captivity to traditional technologies is a result of a number of factors illustrated in Table 6. Education, skills from agricultural training, access to credit, per capita income and positive perception about modern technologies, are positively associated with technology adoption while farmers with parents who are traditionalists have a lower probability of adopting agricultural technologies. Captivity rates were derived from the predicted values of the technology adoption model presented in Table 6. The average predicted adoption rate from the Probit model was found to be 34.8 %, implying that the mean level of captivity of farmers to tradition in Hurungwe District is 65.2 %. This is an indication that Hurungwe District farmers are trapped in traditional production methods.

Table 6: Drivers of technology adoption: Probit model

	(1)	(2)	(3)
Variables	Adoption	Adoption	Adoption
Drought shock (DS)	0.030		
	(0.035)		
Age	0.00001		
	(0.00274)		
Gender (1 for males)	-0.029		
	(0.054)		
Education	0.014**	0.012*	0.011*
	(0.007)	(0.007)	(0.006)
Experience	0.003	0.002	0.002
	(0.003)	(0.002)	(0.002)
Belief (=1 for traditionalists)	0.010	0.008	
	(0.037)	(0.037)	
Training (1 for formally trained)	0.161**	0.161**	0.164**
	(0.072)	(0.075)	(0.071)
Extension	0.0002	0.0002	
	(0.0011)	(0.0011)	
Credit (1 for farmers with credit access)	0.326***	0.326***	0.308***
	(0.044)	(0.043)	(0.043)
Farm size	-0.0008	-0.0004	
	(0.0031)	(0.0031)	
Per capita income	0.001***	0.001***	0.001***
	(0.0003)	(0.0002)	(0.0002)
Perception (1 for modern believers)	0.166***	0.166***	0.158***
	(0.0422)	(0.0420)	(0.0416)
Parent belief (1 for traditional parents)	-0.107***	-0.108***	-0.100***
	(0.040)	(0.040)	(0.0386)
Age square	0.00023		
	(0.00052)		
Constant	-0.549**	-0.598**	-0.425*
	(0.235)	(0.237)	(0.225)
Hazard lambda	-0.269	-0.298	-0.243
Rho	-0.717	-0.773	-0.667
Sigma	0.375	0.385	0.365
Wald Chi-square	330.7***	316.2***	346***
Observations	409	409	409

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Smallholder farmers' vulnerability to consumption shortfall

Table 7 demonstrates differences in age, household size, education, extension contacts and droughts encountered between vulnerable farmers and non-vulnerable farmers.

Table 7: Mean differences between vulnerable farmers and non-vulnerable

Characteristic	Adequate Food (N=227)	Inadequate Food (N=184)	Total (N=411)	Difference
Age in years	41	46	44	-5***
Household size	5	6	5	-1
Education	10	7	9	3***
Number of extension contacts	10	6	9	4**
Droughts experienced	4	5	5	-1***

***, ** and * indicate that the difference between farmers who had adequate food and those who experienced consumption shortfall in the 2013/14 drought shock is statistically significant at 1, 5 and 10 % level, respectively. Differences in means were tested using t-tests for equality of means and Levene's test for equality of variances.

Farmers who belong to the vulnerable group are older, less educated and meet extension officers less frequently. Vulnerable farmers have a mean age of 46 years while non-vulnerable farmers have a mean age of 41 years. The mean difference of 5 years is statistically significant at 1% level. The average education is 3 years lower in the vulnerable group and this difference is statistically significant at 1% level. Visits by extension officers in the vulnerable group are less than in the non-vulnerable group by 4 and the difference is statistically significant at 5% level. The vulnerable group has more years of drought experience compared to the non-vulnerable group. On average, the vulnerable group has experienced a total of 6 droughts while the non-vulnerable group has experienced 5 droughts. The difference of one year is statistically significant at 1% level. Despite the vulnerable group having a bigger average household size, the difference of one individual is not statistically significant (see Table 7). These statistics suggest the importance of providing education and extension services to farmers.

The statistics divulge crucial information for the government with regards to the provision of drought relief. The statistics indicate that the vulnerable group mostly comprises of the elderly farmers as demonstrated by a bigger average age. In addition, women farmers are more vulnerable compared to male farmers. Of the 95 female farmers, only 35.8 % had adequate food during the 2013/14 drought. In contrast, 61.1 % of the male farmers had adequate food during the drought shock. The findings generally show that more than half of the women farmers are vulnerable to drought risk while less than half of the male farmers are vulnerable. These statistics point to the need for gender-based drought relief programmes which have not been common in Zimbabwe.

Despite experiencing drought conditions in the 2013/14 season, many farmers in Hurungwe District managed to produce enough maize for consumption. About 54 % of the farmers produced sufficient maize to exceed the food poverty line. However, the findings show some significant differences between farmers with adequate food (not vulnerable) and those without (vulnerable), in terms of their poverty severity status, technical efficiency and technology adoption propensities. Table 8 presents the differences between the two groups of farmers (farmers without consumption shortfall and those who experienced a shortfall in the 2013/14 drought shock).

Table 8: Mean differences between farmers with adequate food and farmers without

Characteristic	Adequate Food (N=227)	Inadequate Food (N=184)	Total (N=411)	Difference
Technical efficiency	0.565	0.318	0.453	0.247***
Poverty severity	0.801	0.877	0.835	-0.076***
Technology adoption	0.509	0.146	0.348	0.363***
Degree of captivity to tradition	0.491	0.854	0.652	-0.363***

***, ** and * indicate that the difference between farmers who had adequate food and those who experienced consumption shortfall in the 2013/14 drought shock is statistically significant at 1, 5 and 10 % level, respectively. Differences in means were tested using t-tests for equality of means and Levene's test for equality of variances.

The descriptive statistics in Table 8 reveal that farmers who had sufficient food during the 2013/14 drought shock are more efficient than those who experienced consumption shortfall. Farmers who experienced consumption shortfall are 24.7 % less efficient than those with enough food and this difference is statistically significant at 1 % level. In addition, poverty is more severe for farmers who belong to this category. On average, poverty is 7.6 % more severe in the category of farmers who experienced consumption shortfall during the 2013/14 drought. This difference is statistically significant at 1% level. Not only does Table 4 show that drought risk leads to loss of technical efficiency and increased poverty amongst smallholder farmers, but inefficient and poor farmers are likely to be more vulnerable to drought risk than efficient and rich farmers.

In terms of technology adoption, the findings in Table 8 further show that farmers with a higher propensity to adopt modern agricultural technologies are more likely to be food secure during drought years. The propensity to adopt modern agricultural technologies by farmers who experienced consumption shortfall during the 2013/14 drought is 36.3% lower than that of farmers without a shortfall and the difference is statistically significant at 1% level. The mean propensity to adopt modern technologies is 50.9% for farmers not vulnerable to the 2013/14 drought shock and only 14.6% for farmers vulnerable to the drought shock. These statistics point to an important policy implication that farmers with higher propensity to adopt modern agricultural technologies are less vulnerable to consumption shortfalls or that farmers who are captive to tradition are more vulnerable to drought risks.

The estimated Probit model is presented in Table 9 and the marginal effects are presented in the subsequent Table 10. The Pseudo R-squared of 49.8% indicates that the model fits the data well and in cross-sectional data such a value is sufficient to suggest a well-fitting model. In addition to the satisfactory Pseudo R-squared, the Hosmer-Lemeshow test in Table 10 fails to reject the null hypothesis that the model is of good fit. The statistic produced 352 covariate patterns from 354 observations giving a Chi-square value of 183.4 with a p-value of 21.2 %. This statistic is further supported by the Hosmer-Lemeshow Chi-square statistic of 10.3 with a p-value of 24.3% which suggests a well-fitting model.

Table 9: Probit regression of food adequacy on its explanatory variables

Food Adequacy (*FA*)	Coefficient	Standard Error	z-statistic
Poverty severity (*Pov*)	-1.154	0.224	-5.15***
Technical efficiency (*Eff*)	0.407	0.051	7.98***
Captivity to tradition (*CapTr*)	-0.687	0.312	-2.20**
Number of Droughts	-0.138	0.053	-2.59**
Gender (Male = 1)	0.710	0.256	2.77***
Age	0.008	0.010	0.81
Education	0.003	0.041	0.07
Weather forecasting (Modern = 1)	0.102	0.214	0.47
Household size	0.062	0.034	1.81*

***, ** and * indicate that the coefficient of the explanatory variable is statistically significant at 1, 5 and 10 % level, respectively.

Table 10: Marginal effects from probit regression evaluated at means

Food Adequacy (*FA*)	dy/dx	Standard Error	z-statistic
Poverty severity (*Pov*)	-0.227	0.038	5.97***
Technical efficiency (*Eff*)	0.081	0.008	10.10***
Captivity to tradition (*CapTr*)	-0.143	0.064	-2.22**
Number of Droughts	-0.027	0.010	-2.66***
Gender (Male = 1)	0.140	0.049	2.88***
Age	0.001	0.002	0.50
Education	0.001	0.008	0.13
Weather forecasting (Modern = 1)	0.020	0.042	0.48
Household size	0.012	0.007	1.84*

Hosmer-Lemeshow test for goodness of fit

Goodness-of-Fit Evaluation for Binary Specification				
H-L Statistic	10.3244	Prob. Chi-Sq(8)	0.2430	

***, ** and * indicate that the marginal effect of the explanatory variable is statistically significant at 1, 5 and 10 % level, respectively.

The findings in Tables 9 and 10 show that poverty, inefficiency, captivity to tradition, drought frequencies (number of droughts), gender and household size explain farmers' vulnerability to consumption shortfall. The coefficients of poverty, technical efficiency and gender are statistically significant at 1% level while those of captivity to tradition and drought frequencies are statistically significant at 5% level. Only the coefficient of household size is statistically significant at 10% level. Similarly, the marginal effects of these variables are statistically significant (see Table 10). Nevertheless, the coefficients of age, education and methods used by farmers for weather forecasting are not statistically significant despite having the expected signs. Many studies (Below *et al*., 2010; Mutasa, 2010 and Adepetu & Berthe, 2007) have, however, established a statistically significant coefficient of education.

Marginal effects from Table 10 show that a marginal increase in the degree of captivity to tradition reduces the probability of a farmer having adequate food by 0.14 during a drought shock. In other words, an increase in the degree of captivity to tradition increases the farmer's vulnerability to consumption shortfall during a drought year. The results confirm the findings established by Oyekale & Oladele (2012), Vicente-Serrano *et al*. (2012), Kokate *et al*. (2010), Below *et al*. (2010), Sarker *et al*. (2008), Hassan & Nhemachena (2008), Adepetu & Berthe (2007), Omolehin *et al*. (2007), and Wossink *et al*. (1995) while refuting the findings established by Egeru (2012), Nakashima *et al*. (2012), Nyong *et al*. (2007), Macchi *et al*. (2008), Alvarez & Vilca (2008) and Robinson & Hebert (2001). Farmers with a smaller propensity to adopt modern technologies are more vulnerable to consumption shortfall during drought years, that is, farmers enslaved to traditional production systems have a higher risk of producing insufficient food during droughts. This finding points to the importance of technology adoption by smallholder farmers in a changing climate.

Resource-constrained and inefficient farmers have a higher probability of falling into consumption shortfall during droughts, that is, increases in poverty and inefficiency will increase farmers' vulnerability to drought risk. The results presented in Table 10 demonstrate that a marginal increase in poverty severity amongst farmers reduces their probability of having adequate food during a drought shock by 0.23. Similarly, a marginal increase in technical inefficiency of farmers reduces farmers' probability of having adequate food during a drought shock by 0.08. The finding that poor farmers have a higher risk of falling into consumption shortfall during droughts confirms the IPCC (2012) framework linking poverty to farmers' vulnerability. In general, the findings reveal that poverty and inefficiency increase farmers' vulnerability to the risk of consumption shortfall during drought.

Increased drought frequencies increase farmers' vulnerability to the risk of consumption shortfall during droughts. The findings in Table 6 further show that a unit increase in the number of droughts reduces the probability of a farmer having adequate food during a drought year by 0.03. The main implication of such finding is that the increased drought frequencies from a changing climate will intensify farmers' vulnerability to drought risks in the future. Female farmers are more vulnerable to these risks as demonstrated in Table 10. Being female reduces the probability of having adequate food by 0.14. In other words, the findings show that male farmers have 0.14 greater chances of having adequate food during droughts than their female counterparts. Furthermore, the findings show that increasing household size reduces farmers' vulnerable to the risk of consumption shortfall although the coefficient has a weak statistical significance.

CONCLUSION AND POLICY IMPLICATIONS

Conclusion

Generally, the findings point to a high degree of farmers' captivity to traditional technologies caused by insufficient exposure, insufficient education and training, lack of credit markets, low incomes, negative perception about modern technologies and inheritance of parental beliefs. The results demonstrate that farmers trapped in traditional production technologies have a higher probability of falling into consumption shortfall during a drought shock. This, therefore, supports the hypothesis that farmers who are captive to traditional technologies are likely to be more vulnerable to consumption shortfall during a drought shock. This finding refutes the traditional school of thought which advocates for continued use of traditional practices (see Egeru, 2012; Nakashima *et al*., 2012; Nyong *et al*., 2007; Macchi *et al*., 2008; Alvarez & Vilca, 2008 and Robinson & Hebert, 2001). In addition, the results also show that farmers' vulnerability to consumption shortfall is increased by increased poverty levels, low levels of technical efficiency, increased drought frequencies and being female.

Recommendations

The main policy implications and recommendations derived from these findings are: Firstly, the continued use of traditional production methods in a changing climate will increase farmers' vulnerability to consumption shortfall. Effort must, therefore, be made towards developing strategies and policies that promote the adoption of new technologies by smallholder farmers. In this regard, the study recommends interventions that increase farmers' exposure to new technologies, avail affordable credit and provide education & training to farmers. Secondly, vulnerability is likely to increase due to increasing drought frequencies. Hence, achieving the SDG goal of poverty elimination by 2030 may be an uphill task if no interventions in mitigation are put in place. Interventions must, therefore, be directed towards improving water harvesting methods and promoting climate smart agriculture. Thirdly, vulnerability to consumption shortfall during a drought shock is higher for female farmers. So an effective intervention in agriculture must be gender-sensitive. Agricultural support policies (drought relief, subsidies and taxes) must be designed in line with gender distribution. Fourthly, inefficient and poor farmers have a higher probability of falling into consumption shortfall during a drought shock. The main implication of this finding is that poverty cycles continue to put farmers in the risk of consumption shortfall during droughts. The study recommends poverty-cycle breaking interventions such as the provision of affordable education for the poor and input subsidies, among others.

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CHAPTER **04**

DETERMINANTS OF HOUSEHOLD FOOD SECURITY USING HIERARCHICAL LINEAR MODELLING (HLM) TECHNIQUE: A CASE STUDY OF SMALLHOLDER FARMERS IN HWEDZA DISTRICT IN ZIMBABWE

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Abstract
Climate change is a major impediment to rain-fed agricultural production particularly in developing countries in Sub Saharan Africa. This paper examines institutional and agroecological factors that influence smallholder farmers' food security under changing climatic conditions in the Hwedza District in Zimbabwe. Data for this study were collected from 400 randomly selected smallholder farmers, using a structured questionnaire, focus group discussions and key informant interviews. The study used a Hierarchical Linear modelling approach to examine the factors that influence smallholder farmers' food security in the face of climate change. Results from the study show that smallholder farmers' food security is conditioned by access to agricultural extension services, ownership of small livestock and access to common-pool natural resources. We, therefore, conclude that ecological factors play a very important role in enhancing household food security in the face of climate change. This study recommends that household food security can be enhanced by improving access to agricultural services, common-pool natural resources and promoting pass-on small livestock schemes.

Keywords: *climate change, food security, smallholder farmers, Hierarchical Linear Modeling, institutional and ecological*

INTRODUCTION

Climate change is adversely impacting rain-fed agricultural production, food security and nutrition among smallholder farmers particularly in Sub-Saharan Africa (Oduniyi, Tekana, & Casadevall, 2019). In this region, smallholder farmers are very vulnerable to climate-induced food security shocks due to lack of financial resources to implement adaptation strategies (Hallegatte, Vogt-Schilb, Bangalore, & Rozenberg, 2017) and the presence of other production constraining factors such as declining soil fertility, dysfunctional markets (Zamasiya & Nyikahadzoi, 2018; Vanlauwe *et al*., 2010) and low levels of productivity-enhancing and yield-enhancing technologies (Zilberman, Zhao, & Heiman, 2012). Per capita, food production is declining at a time when the population growth is increasing (Hall *et al.,* 2017) and this is worsening food insecurity. It is estimated that one in four people in this region is undernourished and lack sufficient nutritious food for an active and healthy life (Fraval, *et al*., 2019). The State of Food Security and Nutrition Report notes that globally, over 821 million people are hungry and the majority of these are in Sub-Saharan Africa (FAO, IFAD, UNICEF, WFP, & WHO, 2019). This development is exacerbating the risk of malnutrition, poor health and retardation of human development. The high food insecurity being experienced in Sub-Saharan Africa casts doubts on the region's ability to achieve the UN's Agenda for Sustainable Development target of zero hunger by 2030. Unfortunately, food insecurity in Sub-Saharan Africa is worsening at a time when its population is increasing and the region is fighting the adverse effects of climate change on agricultural production (Zhou *et al.,* 2017). Despite being under pressure from climate change, the smallholder farmers have no means to arrest the sharp decline in food security due to the devastating effects of climate and the low productivity on largely sandy soils (Rukuni, 2002). Without deliberate policies to address the food insecurity situation in Sub-Saharan Africa, this problem will continue to haunt policymakers as thousands will plunge into abject poverty.

Several studies have been conducted to interrogate how climate change affects food security and agricultural production (Donatti et al., 2018; Harvey *et al*., 2018; Chang & Bonnette, 2016; Mendelsohn, 2008; Kurukulasuriya & Mendelsohn, 2008). Despite these studies, the effect of climate change on food insecurity is complex and poorly understood, particularly for developing countries. While food insecurity is widespread in semi-arid regions, studies show that even the areas with higher agro-ecological potential are experiencing increased food insecurity (Zamasiya, Nyikahadzoi & Mukamuri, 2017; USAID, 2018; Rurinda *et al*., 2013). At a household level, food insecurity occurs when members of the household at all times do not have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for active and healthy life (Pollard & Booth, 2019; Escamilla, 2017). In developing countries, the list of the causes of food insecurity is long and multi-faceted.

Literature suggests that food security is a multidimensional problem that ranges from global, regional, national, local, household to the individual (Zhou *et al.,* 2017). At each of these levels, the determinants of food insecurity differ also. Some scholars argue that food insecurity in developing countries is conditioned by macroeconomic factors, poverty, population growth, social norms, health, soil fertility, lack of productive assets, climate change and inelasticity of food production (Escamilla, 2017; Ilaboya *et al.,* 2012; Sasson, 2012). These studies suggest that to address food insecurity for a country like Zimbabwe, there is a need for a multi-dimensional approach. Chagutah (2010) observes that in Zimbabwe, food-consumption outweighs food-production in most seasons. He argues that the production deficit cannot only be ascribed to climate change but a host of other factors. Several studies have been conducted at the household level to investigate the drivers of food security among smallholder farmers (Niles & Salerno, 2018; Zhou *et al.,* 2017; Mango *et al.,* 2014; Gebre, 2012; Bogale & Shimelis, 2009). In all these studies, household factors (household size, access to labour, farmer's age, farmer's educational level, off-farm income), socioeconomic (livestock ownership, land-ownership, size of arable land) and institutional factors (access to credit, access to markets, access to extension services). An emerging pattern from these studies is that addressing food insecurity requires a multi-pronged approach.

Although household, socioeconomic and institutional factors have been proffered in literature as drivers of food insecurity among smallholder farmers, other scholars observe that climate change in the form of droughts is the major determinant of food security in rain-fed agricultural production systems (Lunduka *et al.,* 2017; Shiferaw *et al.,* 2011; Lobell *et al.,* 2011). Daryanto, Wang, & Jacinthe (2016) observe that a mid-season drought during the vegetative and productive phases can result in yield reduction by over 39.9%. Cairns, *et al*., (2012) note that the predicted temperature rise of 2.1–3.6°C by 2050 will have negative implications on food security in developing countries. This evidence suggests that Zimbabwe faces high food insecurity, particularly during drought or poor rainfall years. While food aid by Non-Governmental Organisations and the government complements maize supplies during lean seasons, this support is not enough to cater for the dietary needs of the food-insecure households (Chagutah, 2010). Despite the ravaging effects of climate-induced droughts and the inability of NGOs to provide enough food to all food-insecure households, interestingly, these communities still manage to get to the next harvest. Scholars further observe that even in seemingly good rainfall years, most smallholder farmers fail to produce food that is enough for their household consumption (Apanovich & Mazur, 2018; Ali & Erenstein, 2017; Nilees & Brown, 2017).

The Integrated Food Security Analysis Phase Classification (IPC) observes that food insecurity is increasingly becoming a major problem for most smallholder farmers and a national security threat in Zimbabwe. Their 2019 report notes that over 25% of Zimbabwe's population was facing moderate food insecurity gaps and households were marginally able to meet minimum food needs by depleting essential assets or employing crisis or emergency coping strategies. This was due to drought, Cyclone Idai and hyperinflation which reduces purchasing power and access to food. Further, in the 2018/2019 agricultural season, Zimbabwe experienced a drought resulting in large-scale crop failure and acute food insecurity. Estimates from the Zimbabwe Vulnerability Assessment Committee projects show that over 5.5 million rural people were food-insecure at the peak of the 2019/20 season and over 3.3 million were estimated to be in urgent need of food assistance (FNC, 2019). In responding to the escalating levels of food insecurity, the Government of Zimbabwe (Government) is collaborating with development partners in proffering yield-enhancing technologies to smallholder farmers to improve household food security and nutrition. The technologies that are being proffered include Integrated Soil Fertility Management, Climate Smart Agricultural practices and conservation agriculture technologies. These technologies are being disseminated through learning centres, as well as farmer field schools and demonstrations. Hwedza in Zimbabwe is one of the areas where several developments and research partners were collaborating with the Government in addressing food insecurity among smallholder farmers. Results from the interventions show that Hwedza district has a high potential for improving food security through the use of these yield-enhancing technologies. However, despite the immense investment in the dissemination of agricultural yield-enhancing technologies, food insecurity remains a major challenge in the district as reported in ZimVac reports. Given the disparity between research-led trials and smallholder farmers' yields, one wonders as to how food insecurity in the district can be enhanced in the face of climate change. The objective of this research is therefore to identify the household and agro-ecological level factors that influence household food security among the smallholder farmers in Hwedza district.

Several studies have been conducted on the drivers of household food security among smallholder farmers (Niles & Salerno, 2018; Zhou *et al.,* 2017; Shisanya & Mafongoya, 2016; Nyikahadzoi *et al.,* 2012; Gebre, 2012; Bogale & Shimelis, 2009). Niles & Salerno (2018) used a multiple linear regression model to examine the association between food insecurity and climate shocks in 15 countries in Latin America, Africa and South Asia. Results from these studies provide insights to policymakers on how they can enhance food security among smallholder farmers. However, a major challenge in these studies is the use of linear regression (Nyikahadzoi, *et al*., 2012), binary model (Abdullah *et al*., 2017; Gebre, 2012; Bogale & Shimelis, 2009) and partial correlation analysis (Nyikahadzoi *et al*., 2017; Shisanya & Mafongoya (2016), which fail to recognise the role played by agroecological systems in enhancing household food security. Further, simplistic modelling techniques may lead to unreasonable estimates especially when the unit of analysis is nested in clusters. The use of the Hierarchical Linear Regression Modelling is thus recommended as a panacea for the drawback of these models (Woltman *et al.,* 2012). The HLM regression analysis recognises that households are nested in different hierarchies (Huta, 2014) such as villages, and wards. This modelling approach enables the estimation of drivers of non-farm based adaptation strategies used to secure food security among smallholder farmers (Woltman *et al*., 2012). This chapter examines institutional and agro-ecological factors that influence smallholder farmers' food security under changing climatic conditions in the Hwedza District in Zimbabwe.

DESCRIPTION OF THE STUDY AREAS AND METHODOLOGY

Study site

Research whose results are being presented in this chapter was conducted in Dendenyore and Ushe wards in Hwedza District in Mashonaland East Province of Zimbabwe. Hwedza District is a communal area dominated by subsistence rain-fed maize production under harsh climatic conditions (Zamasiya, Nyikahadzoi & Mukamuri, 2017). Smallholder farmers in Hwedza District grow groundnuts, finger millet, and cowpeas on small plots (Zamasiya, Nyikahadzoi, & Mukamuri, 2018). Dendenyore Ward lies in Natural Farming Region 2b and receives an annual average rainfall of 750mm (Rurinda *et al*., 2013). The predominant soils in Dendenoyre Ward are sandy-loam. The ward has a small dam which supports subsistence irrigation. Ushe Ward lies in Natural Farming Region 3 which receives an annual average rainfall of 650mm-800mm between November and March (Rurinda *et al*., 2014). The predominant soils in Ushe Ward are coarse to sandy soils derived from granitic rocks. In these wards, maize is produced under rain-fed conditions. A key feature of the two wards is that they lie in transitional climate zones. The climate in Dendenyore and Ushe wards is drifting towards Natural Farming Region 3 and 4 respectively. Ushe Ward experiences frequent droughts and rising temperatures and is now known as a "climate hotspot". During lean seasons, most farming households in Hwedza district rely on the extraction of common-pool natural resources such as Chakata (*Parinari Curatellifolia)*, Mashuku (*Uapaca Kirkiana*) to supplement their diets (Woittiez *et al.,* 2013).

Livestock-rearing, mostly cattle, goats and indigenous chickens, complement subsistence crop-production activities. Scholars observe that during poor agricultural seasons, smallholder farmers complement their maize-based diets with edible wild fruits (Woittiez *et al*., 2013) and indigenous vegetables (Chagumaira *et al.,* 2015) and food aid from Non-Governmental Organisations (Chagutah, 2010). Since 2000, Hwedza District has been experiencing increased variability in the onset of rains, rising temperatures and a decline in the quality of rainfall seasons (Zamasiya, Nyikahadzoi & Mukamuri, 2017; Rurinda *et al*., 2013). The frequency of droughts is increasing, and good quality seasons are increasingly becoming fewer since 2000 (Rurinda *et al*., 2014). The number of bad seasons is outweighing good rainfall seasons (Zamasiya, Nyikahadzoi & Mukamuri, 2017). The IPC notes that Hwedza District is one of the districts with high agro-ecological potential but has been increasingly experiencing food insecurity in the past 20 years. For instance, in 2019, over 10% of the households in Hwedza District were classified as being under acute food insecurity stress. The district was a site for the Sub-Saharan Africa Program (SSACP) which was testing the Integrated Agricultural for Research Development concept. The SSCAP piloted innovations on improving smallholder productivity, income and nutrition. Some of the technologies being piloted include integrated soil fertility management and conservation agriculture step trials. Despite these interventions, food insecurity in the district is still very high compared to other districts. The 2019 ZimVac Report notes that Hwedza District is one of the districts that is most prone to acute food shortages. The district's dietary diversity score has fallen from 6.3 to 4.4 (FNC, 2019). The above factors made Hwedza District an interesting case study for this research.

Study Site Selection and Sampling

This study used a multistage sampling technique to select the study site and the survey respondents. In the first stage, the study used purposive sampling to select the Hwedza District. This district was purposively selected on the basis that the district has high agro-ecological potential, low dietary diversity and experiences acute food shortages. Rurinda *et al*., (2013) and Stage two involved the use of a random sampling technique to select two wards from a total of 22 wards in Hwedza District. In the third stage, simple random sampling was used to select 10 villages per ward. Dendenyore Ward has a total of 30 villages and Ushe Ward has 22 villages. This resulted in 20 villages being selected for the study. Finally, the study used a simple random sampling technique to select 20 smallholder farming households in each village. This approach resulted in 400 smallholder farmers being selected for the interviews. This sample size was guided by the following formula:

The sample size used in this study is based on the following formula.

$$n = Z^2 \frac{(1-p)(p)}{d^2} \quad (1)$$

Where:

n=required sample size;

Z=95% confidence interval (standard value of 1.96),

p=50% or 0.5 based on default value and

d=5% margin of error

$$n = 1.96^2 \frac{(1-0.5)(0.5)}{0.05^2} \quad (2)$$

=384.16 households

Therefore, the required minimum sample size for this study is 384 smallholder farmers. A sample size of 400 smallholder farmers is therefore deemed moderate and is above the recommended sample size of 384 at 5% tolerated error and 95% confidence interval.

Data Sources and Collection Methods

This study used quantitative and qualitative data to address the objective of the research. Quantitative data was collected from the sampled 400 smallholder farmers using a structured questionnaire. The questionnaire was administered through face to face interviews. This structured questionnaire was used to collect data on demographic information, farm-based adaptation practices, non-farm based adaptation practices used by smallholder farmers to respond to climate change, household food security, access to the main food groups, access to extension services, remittances, and challenges experienced by farmers in adapting to climate change. The study collected qualitative data using Focus Group Discussions (FGDs), and Key Informant Interviews (KIIs). Purposive sampling technique was used to select participants for the key informant interviews. The KIIs who participated in the study are ward level Agricultural Extension Officers (AEOs), and district level extension officers. This selection resulted in 8 AEOs participating in the study. Further qualitative data were collected from 6 knowledgeable farmers through key informant interviews. In this study, knowledgeable farmers are smallholders who have at least 30 years of consistently conducting smallholder farming activities in the Hwedza District. In each selected village, an FGD was conducted with 12 smallholder farmers (6 males and 6 females). The purpose of conducting FGDs was to solicit data on the average rating of the village's perception of the level of natural resources in each village, the farming practices used by smallholder farmers, and the challenges that they are experiencing in adapting.

Analytical Framework

This study used the Hierarchical Linear Modeling (HLM) technique to determine the non-farm based adaptation practices used by smallholders to secure household food security in Hwedza District of Zimbabwe. Hierarchical Linear Modeling techniques are used to analyse the relationship between an outcome variable and independent variables that are nested at different hierarchies such as individual (demographic, socioeconomic, institutional) and community-level factors (Frankenberger *et al.,* 2013; Woltman *et al.,* 2012). The major strength of the HLM technique is that it partitions variance across the levels of analysis (Huta, 2014) and enables the estimation of the contribution of each level to the overall outcome. In this study, we assume that smallholder farmers are nested in villages. For our analysis, we adopt a two Level HLM approach. In this study, the Level 1 variables are household level variables and Level 2 covariates are village-level variables.

Specification of a Hierarchical Linear Model

In this study, we model the Food Consumption Score (a proxy for food security) as a function of farmer-level and village-level characteristics. In this case, our dependent variable is household Food Consumption Score. The household level (Level 1) independent variables are household age, household age squared, household size, sex of household head, small livestock index, access to remittances, access to the extension. In this study, the level 2 variable is natural resources index. To achieve our objective, the HLM technique follows three basic steps that are an estimation of the (1) Random Effects or Fully unconditional model with Level 1 covariates (2) Random Intercept Model and (3) the HLM model with Level 2 covariates. These steps are explained in the next section.

Step 1: The Random Effects Model

The Random Effects Model helps to determine the portion or estimates of the variance in the modified Food Consumption Score that is due to cross-village variation. This stage involves running the model without entering in any explanatory variables from Level 1 or 2. The Random Effects Model can be represented as follows;

Yij= Boj +rij for farmer i in village j (1)

$B_{oj} = v_{oo} + z_{oj}$ (2)

combining (1) and (2), we have Y ij= voo +zoj +rij (3)

Where:

Y_{ij} = food security for household *i* in village *j*

B_{oj}= mean food security in village *j*

v_{oo}= grand mean food security across all villages

r_{ij} =error term associated with each observation.

z_{oj} = shows how the mean food security in a village deviates from the grand mean

Step 2: The Random Intercept model

The purpose of the Random Intercept Model is to test the relationship between Level 1 predictors and food security (Huta, 2014). This step involves the addition of level one (individual level) independent variables that condition food security assuming fixed effects. In the Random Intercept Model, the intercept is allowed to vary across villages. This is done to accommodate cross-village differences in food security. The general Random Intercept Model can be presented as follows:

$Y_{ij} = v_{oo} + v_{1j}X_{1ij} + v_{2j}X_{2ij} + v_{3j}X_{3ij} + v_{4j}rX_{4ij} + v_{5j}X_{5ij} + v_{6j}X_{6ij} + v_{7j}X_{7ij} {}_{+} v_{8j}X_{8ij} + z_{oj} + r_{ij}$ (4)

Where:

V_{1j}............V_{8j} are coefficients for level 1 explanatory variables

X_{1ij}............ X_{8ij} are level $_1$ explanatory variables

Subscript j is for the individual villages from (*j*=1.............J). The subscript *i* is for the individual smallholder farmers (*i*= 1.....n_j)

The specific equation can then be written as follows:

$Y_{ij} = v_{oo} + v_{10}farmersage_j + v_{20}farmerage\ squared_{ij} + v_{30}farmersex_{ij} + v_{40}farmereducation_{ij} + v_{50}housesize_{ij} + v_{60}extension_{ij} + v_{70}remittances_{ij} + v_{80}smalllivestockindex_{ij} + z_{oj} + r_{ij}$ (5)

The variables that are retained in this model are based on iterations and contribution to variance.

Stage 3: HLM with Random intercept and Level 2 covariates

The HLM with Random intercept and Level 2 covariates includes Level 1 covariates, Level 2 covariates and a random intercept. In our case, it is the addition of the Natural Resources Index as the only Level 2 covariate. The specification of the HLM with random intercept and Level 2 covariates is as follows:

$Y_{ij} = v_{oo} + v_{1j}farmer'age_{ij} + v_{2j}farmer'sgesquared_{ij} + v_{3j}farmer'sex_{ij} + v_{4j}farmers'education_{ij} + v_{5j}housesize_{ij} + v_{6j}extension_{ij} + v_{7j}remittances_{ij} + v_{8j}smalllivestockindex_{ij} + z_{oj} + r_{ij}$ (6)

Adding the Level 2 variable Natresources to equation (6), we have the following equation:

$Y_{ij} = v_{oo} + v_{1j}age_{ij} + v_{2j}sex_{ij} + v_{30}extension_{ij} + v_{4j}remittances_{ij} + v_{5j}smalllivestock_{ij} + v_{6j}education_{ij} + v_{7j}farmers'age_{ij} + v_{8j}farmer'agesquared_{ij} + V_jNatresources + Z_{oj} + r_{ij}$ (7)

The final form of this model is arrived at after using extrapolation on each combination of level one covariates and level two covariates by checking their contribution to variance. The Level 1 covariates that are retained are those that contribute the most variance to the intraclass correlation coefficient.

The Level 2 variable Natural Resources Index was obtained from FGDs. During group discussions, smallholder farmers were asked to name the foods that they derive from their indigenous forests. They then rated their level of access to indigenous vegetables and access to edible wild fruits from indigenous forests within their villages. The rating was done on a scale of 1-10 with 1 being the least and 10 being most. The total score was then divided by two to get the Natural Resources Index per each village 2.

Dependent variable

The dependent variable is food security as measured by a household's Food Consumption Score (FCS). The modified FCS is a composite food security indicator that is based on dietary diversity, food consumption frequencies and nutritional importance of the major food groups (WFP, 2016). This measure captures the dietary diversity and food frequency regardless of the source of the food. During the survey conducted in February 2015, smallholder farmers were asked if they had consumed any foods from the 8 major food groups in the 7 days. Those who answered, "Yes", to this question were then asked to indicate the number of times that they had consumed the food in the past seven days. The maximum number of times that a person can consume a particular food group is seven. Based on the responses, the FCS was then computed as follows:

Food Consumption Score (FCS) = $W_{staple}X_{staple} + W_{pulse}X_{pulse} + W_{veg}X_{veg} + W_{fruit}X_{fruit} + W_{meat}X_{meat} + W_{sugar}X_{sugar} + W_{dairy}X_{dairy} + W_{oil}X_{oil}$

X_i =Frequencies of food consumption

W_i =Weight of each food group as provided for by WFP (2007). The distribution of weights as are as follows; staples =2, pulses =3, vegetables =1, fruit =1, meat/fish =4, milk =4, sugar =0.5 and oil = 0.5

In this study, our innovation in computing the

FCS is that we identified indigenous foods that the smallholder farmers are deriving from the indigenous forests within their villages. These foods include indigenous fruits, indigenous vegetables and honey.

Independent variables

The independent variables that are used in this study are to farmer's age, farmer's age squared, farmer sex, farmer's education, farmer's household size, extension, access to remittances, and small livestock index. The Level 3 variable is Natural Resources Index. These variables have been chosen based on literature and context. These variables are presented in Table 1.

Table 1: Description of independent variables

Variable	**Description**	**Expected sign**	**Level on HLM**
Dependent Variable			
Modified Food Consumption Score	Food Security Index		n/a
Independent variables			
Level one independent variables			
Head age	Farmer's age in years	+/-	1
Headage squared	The square of a farmer's age		1
Head sex	Whether sex of farmer's household head is male =1 otherwise 0	+	1
Head Education	Number of years a farming household head spent in formal education	+	1
Access to Remittances	Whether a farmer's household has access to remittances, if yes =1, otherwise 0	+	1
Access to extension	Whether farmer's household has access to extension services, if yes =1 otherwise 0	+	1
Household size	Number of members in the farmer's household	+/-	1
Small livestock Index	Index for farming household's ownership of small livestock	+	1
Level two-Independent variable			
Natural Resources Index	Index for a village's endowment of natural resources	+	2

This study used a number of hypotheses. First, we hypothesized a positive relationship between household head's education level and household food security. This was based on the findings of Mulwa *et al.,* (2017) who found that education improves human capital and increases a smallholder farmer's keenness to adopt agricultural technologies and management practices that can improve their household food security (Zamasiya & Nyikahadzoi, 2018). In support of this argument, Zamasiya, Nyikahadzoi, & Mukamuri (2018b) also found that smallholder farmers who are learned are more likely to have access to information on technologies and practices that they can use to improve their food security in the face of climate change. Secondly, the study assumed that male-headed farming household to be more food-secure than female-headed households. This observation is supported by scholars such as Nyikahadzoi *et al.,* (2013), as well as Bogale & Shimelis (2009) who found out that male-headed farming households have better access to labour for the execution of agronomic activities than female-headed households. Male-headed farming households are more likely to use hired labour to implement strategies that can enhance their household food security (Zhou *et al.,* 2017). Because of better access to labour than female-headed households, male-headed households are more likely to execute agronomic and farm management practices on time (Ali & Erenstein, 2017). Further, male-headed farming households are also more likely to have access to production- enhancing technologies that can improve their food security (Nhemachena & Hassan, 2007).

Thirdly, since the household size has an ambiguous relationship with household food security, the study, therefore, expected either a negative or a positive relationship between household size and household food security. Mitiku, Fufa, & Tadese (2012) found that smallholder farmers with larger households have more mouths to feed compared to smaller households. In most circumstances, the higher demand for food in larger farming households cannot be matched with production or purchases from other income. Under such circumstances, the relationship between household size and household food security is expected to be negative. On the other hand, other studies have shown that larger farming households may be more food-secure than smaller farming households (Niles & Salerno, 2018; Aidoo *et al.,* 2013). This is because the larger farming households have more labour resources, can commit more land resources under cultivation and also implement various labour-intensive strategies to enhance their food security.

Fourthly, in the absence of conclusive evidence on the relationship between the age of household head and household food security, the study further assumed that it can be positive or negative. According to Gebre (2012), as well as Bogale and Shimelis (2009), age of the household head is positively correlated with household food security. They observe that older farming households could have more experience in farming, are risk-averse and are likely to have diversified livelihood activities. The scholars also argued that because of the experience, the older farming households are more likely to be food-secure than households that are headed by younger farmers. Further, such households may be relying on retirement grants and NGO social transfers. However, Shisanya & Mafongoya (2016) argue that farming households headed by older people are more likely to be food insecure. They argue that older households are less open to new ideas that they can use to improve food security.

In this study, we hypothesize a positive correlation between household livestock wealth (based on ownership of small livestock) and food security. This argument is based on findings of Zamasiya, Nyikahadzoi & Mukamuri (2018) who note that small livestock plays a very important role in a smallholder farming household for subsistence needs, nutritional requirements, wealth and accumulation. Farming households that own small livestock are better placed to manage climatic risks on agricultural production than their counterparts. This argument is also supported by Amare & Simane (2018) who found that households with small livestock can easily dispose of their livestock and raise funds for food purchases.

We expect a positive correlation between access to extension information and household food security. This argument is based on findings of scholars such as Zamasiya, Nyikahadzoi, & Mukamuri (2017), Ali & Erenstein (2017) and Bedeke *et al.,* (2018) who found that smallholder farming households with access to agricultural extension officers are likely to have information and knowledge on agronomic practices and management practices that they can use to enhance their food security. Such farming households are more likely to be confident in implementing the strategies.

We expect a positive relationship between access to remittances and household food security. This argument is based on several studies that found that access to remittances from family and non-family members represents additional financial resources for a farming household that can be utilized to enhance food security (Zamasiya, Nyikahadzoi & Mukamuri, 2018; Nyikahadzoi *et al*., 2013). These additional financial resources can be used to purchase agricultural inputs, and hire labour services (Nyikahadzoi, *et al*., 2012; Bogale & Shimelis, 2009). Remittances can also be used to augment food reserves during lean periods (Gebre, 2012).

In this study, we expect a positive relationship between households' access to food from the natural agro-ecological system and household food security. This argument is based on several studies. According to Frankenberger *et al.,* (2013), natural resources play a very pivotal role in conditioning communities' resilience to climate change-induced food security shocks. Common pool natural resources act as a safety net for communities during times of crisis such as crop failures, a fallback mechanism in complementing food reserves during food security shocks (Benhura *et al.,* 2013; Woittiez *et al*., 2013). These NTFPs include wild edible fruits such as Chakata or Hacha (*Parinari Curatellifolia)*, Mashuku or Mazhanje (*Uapaca Kirkiana*), honey and indigenous vegetables. Households collect edible fruits such as *Parinari Curatellifolia* for direct consumption or processing into foodstuffs during periods of climate-induced crop failure (Benhura *et al.,* 2013). For instance, Woittiez *et al.,* (2013) observe that 40% of the energy intake for poor households in Hwedza District of Zimbabwe comes from edible wild fruits.

Data Analysis

The study used the Statistical Package for Social Scientists (SPSS) Version 23 for capturing quantitative data and cleaning. The data was imported into STATA 15 for analysis. The results from the quantitative analysis are presented in Tables as coefficients, standard errors and p-values. Qualitative data collected from interviews and focus group discussions and observations were analyzed thematically.

RESULTS

Hierarchical Linear Modeling Estimation Results for drivers of food security

Fully unconditional model or one-way analysis of variance

Table 2: HLM estimation results for the Fully Unconditional Model

Fixed Effect	**Std. Err.**	**Z**	**P>z**	**[95% Conf.**	**Interval]**
Constant	1.39	21.08	0.00	26.56	32.01
Random-effects parameters	**Estimate**	**Std. Err.**	**[95% Conf.**	**Interval]**	
Grouping variable (village)					
var(_cons)	30.15	12.22	13.63	66.72	
var(Residual)	168.78	12.25	146.41	194.56	

LR test vs. linear model: chibar2(01) = 35.34   Prob >= chibar2 = 0.0000

Table 2 presents the estimation results for the Fully Unconditional Model or the Null Model. The results show that the reported LR test statistic is 35.34 (p>Chibar square<1%). The intra-class correlation coefficient (ICC) for this model is;

ICC = (30.15) / (30.15+168.78) = 15.16%.

This result means that approximately 15% of the variance in food consumption scores among smallholder farmers in Hwedza District of Zimbabwe is attributable to village level factors. Since the computed ICC for the Null or Fully Unconditional Model >5%, we conclude that the HLM can be used for this data.

Random Intercept model

Table 3: HLM Results for the Random Intercept Model

Fixed Effects	**Coef.**	**Std. Err.**	**Z**	**P>z**	**[95% Conf. Interval]**	
Small livestock Index	0.05	0.02	2.57	0.01	0.01	0.09
Access to extension services	3.07	1.64	1.88	0.06	-0.14	6.28
Constant	27.24	1.37	19.84	0.00	24.55	29.93
Random-effects Parameters	**Estimate**	**Std. Err.**	**[95% Conf.Interval]**			
Grouping Variable (village)						
var(_cons)	22.48	9.97	9.43	53.59		
var(Residual)	165.69	12.03	143.71	191.04		

Wald chi2(2) = 12.16, Prob > chi2 = 0.0023; LR test vs. linear model: chibar2(01) = 22.20 Prob >= chibar2 = 0.0000

Table 3 presents the HLM estimation results for the Random Intercept Model. The results show that there is a statistically significant relationship between access to agricultural extension services (p<10%) and small livestock Index (p<5%) have a positive effect on Food Consumption Scores across the villages

Hierarchical Linear Regression Model with Random Intercept and 2-level covariates

Table 4: Estimation results for the HLM with Random Intercept and 2-level covariates

FCS	**Coef.**	**Std. Err.**	**Z**	**P>z**	**[95% Conf. Interval]**	
Small Livestock Index	0.05	0.02	2.32		0.01	0.09
Access to extension	3.28	1.62	2.02		0.10	6.46
Natural Resources Index		2.80	4.75		7.82	
_cons		1.34	16.98		20.06	
Random-effects parameters	Estimate	Std. Err.	[95% Conf.Interval]			
Grouping variable (village)						
var(_cons)	5.64	4.55	1.16			
var(Residual)		12.06	144.05			

Wald chi2(3) = 41.48, Prob > chi2 = 0.0000; LR test vs. linear model: chibar2(01) = 2.82 Prob >= chibar2 = 0.0464

Table 4 presents the estimation results of the HLM with Random Intercept and Natural Resources Index as the level 2 covariate. The regression results show that the coefficients of small livestock index (p<5%), access to extension (p<5%) and Natural Resources Index (p<1%), are all significant and they positively influence Food Consumption Scores. Since the Wald test (W=41.48 and p=0.00) and LR = 2.82 (halved p-value of 0.02). The explained variance for this model is 13.67% of the variation in food security.

DISCUSSION OF RESULTS

Study findings show that variables such as farmers' age, farmer's gender, farmer's education, farmer's household size and access to remittances are not statistically significant drivers of household food security among smallholder farmers in Hwedza District of Zimbabwe. These variables were dropped from the model during iterations for the Random Intercept Model. Despite these variables being important in driving food security as highlighted in several studies, the variables were found to be statistically insignificant in determining food security for households in Hwedza District.

Study findings show that the coefficient of natural resources index (p<1%) is statistically significant and has a positive effect on household food security. These findings are consistent with the findings of Frankernberger *et al*., (2013) and Woittiez *et al*., (2013) who also found a positive correlation between access to natural resources and household food security. We observe that when smallholder farmers have access to natural resources such as indigenous forests, they can augment their food supplies by gathering edible wild fruits, indigenous vegetables and mushroom during climate-induced food insecurity shocks. The fruits can be eaten raw or processed into various products that provide much-needed nutrients for household members. As such, smallholder farmers with access to edible wild fruits and indigenous vegetables have better food security than their counterparts. During focus group discussions, smallholder farmers highlighted that during lean agricultural seasons, they owe their existence to the indigenous forests in their villages. These forests provide them with edible wild fruits such as *Parinari Curaterinalia (Chakata), Uapaca Kirkiana (*Mashuku or Mazhanje) and edible insects such as *Gonimbrasia belina* (Mopani worms) and *Isoptera* (Ishwa). The smallholder farmers also highlighted that during droughts, the fruits will be very abundant offering a safety net to communities.

Results from the study show that access to agricultural extension services (p<5%) positively and significantly influences household food security among smallholder farmers. These results are in line with our prior expectation and are consistent with our prior expectations and corroborate with the findings of Ali & Erenstein (2017) who found a positive relationship between access to extension and food security. We find that smallholder farmers with access to agricultural extension services are more food-secure than their counterparts. This is because access to extension services improves farmers' knowledge of climate change, its impacts on agricultural production and the possible adaptation technologies that they can use to address the impact of climate change. As observed by Zamasiya & Nyikahadzoi (2018), extension officers play an important role in technology dissemination. This is because the extension officers decode research information into formats that are well understood by the smallholder farmers. The extension officers are likely to be knowledgeable about how to process edible wild fruits and vegetables. This knowledge will help smallholder farmers improve their food security in the face of climate change.

Research results show that the coefficient of ownership of small livestock (p<5%) is statistically significant and has a positive effect on household food security among smallholder farmers. This result is consistent with our prior expectations and corroborates with the findings of Bogale & Shimelis (2009) and Zamasiya, Nyikahadzoi & Mukamuri (2018) who observe that ownership of small livestock has a positive effect on adaptation and food security. In Zimbabwe, most smallholder farmers are not integrated into the financial system. As such, smallholder farmers in rural areas then use small livestock as a store of value, medium of exchange and a safety net for managing climate-induced shocks.

During lean agricultural seasons or climate-induced shocks, the smallholder farmers who own small livestock can dispose of their livestock to purchase food supplements. During focus group discussions, smallholder farmers highlighted that small livestock are resistant to climate change compared to big livestock such as cattle. This is because the small livestock can survive on leaves and require fewer amounts of water for drinking than cattle. Further, small livestock is also easy to dispose of in smallholder farming communities as the farmers can do barter trade among themselves or they can sell for liquid cash. Smallholder farmers can also slaughter the small livestock for much-needed protein. Households that do not own small livestock engage in detrimental practices to cope with climate-induced food insecurity. The strategies include selling their productive assets. This development makes them less resilient to climate change than those that own small livestock.

CONCLUSION

This study used a Hierarchical Linear Modeling technique to investigate the institutional and ecological factors that affect household food security. The results show household-level factors that usually determine food security among smallholder farmers are not significant for smallholders under climate change. Instead, factors such as access to agricultural extension services, ownership of small livestock and natural resources index condition household food security in the face of climate change. We conclude that for communities that are affected by climate change, macroeconomic conditions, access to remittances and access to input schemes are not important for conditioning food security among smallholder farmers. What the researchers observed is that critical institutions such as extension services play an important role in the dissemination of technologies for managing the impact of climate change among smallholder farmers. Further, the researchers observed that ownership of small livestock is essential for building the resilience of smallholder farmers against climate change. The research also observes that common-pool natural resources such as edible wild fruits and indigenous vegetables that constitute an important dietary component of smallholder farmers, help in assisting communities to fight climate-induced food insecurity.

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CHAPTER **05**

INVESTIGATING THE EFFECTS OF CLIMATE-CHANGE ON HOUSEHOLDS FOOD SECURITY AND COMMUNITY RESPONSE STRATEGIES IN ZIMBABWE: THE CASE OF FEMALE-HEADED HOUSEHOLDS IN WARD 30, BUHERA DISTRICT

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Source: https://www.wikiwand.com/en/Buhera_District

ABSTRACT

This book chapter explores the effects of climate-change on food security within female-headed households and common response strategies used. The study evaluated the perceived effects of climate-change on food security by female heads and resources used in responding. A case study research design in which qualitative data collection methods, namely in-depth interviews, focus group discussions and key informant interviews were used in the data-gathering process. Findings reflect climate-change as negatively affecting food security within female-head households through reduced productivity. Traditional systems and indigenous resources have been useful as a response mechanism among these female-headed households. However, institutional and socio-economic barriers pose as limitations in utilisations of available resources and adoption of climate smart practises for improved households food security. Policies and programs that promote equitable access to resources and services, take into account gender norms and values and promote the use of indigenous resources in an efficient manner remain relevant.

Keywords: climate-change, food security, female heads, social safety nets, climate smart practices

INTRODUCTION AND BACKGROUND

Climate-change is increasingly recognized as a global phenomenon with potentially far-reaching implications (Stern, 2006; IPCC, 2007; IPCC, 2014). Sub-Saharan Africa, including Zimbabwe, has already started experiencing changes in rainfall patterns, characterised by increases in the frequency of both floods and droughts (Holmgren *et al*, 2006; Brown, 2012; ZHDR 2017). These changes are already undermining gains of agriculture research and development designed to secure households food security among smallholder farmers. As a result of the above changes, climate-change is expected to push more than 600 million people into malnutrition by 2080 (UNDP, 2008 Nelson *et al*., 2010; Karfakis *et al*, 2012).

Female heads, an already highly vulnerable food insecure group, are likely to suffer the most due to heavy reliance on climate-sensitive rain-fed agriculture and natural resource for food and income (Horrel *et al*, 2006; Mallick *et al*, 2010; Kotir, 2011, Tibesigwa *et al,* 2015, Alhasan *et al*, 2019). The high levels of poverty marked by low incomes associated with female-headed households also impinge on their adaptive capacity (Buvinic *et a*l, 1997; Kates,2000; Schulze, 2010). The current global trends point to the increase in the numbers of female-headed households, with the majority of them in rural areas of Sub-Saharan Africa (Horrel & Krishnan, 2006). This region comprises several poor countries already struggling to cope with the effects of extreme weather conditions and accelerated effects of climate-change, posing a greater risk to female headed-households food security needs.

Female-headed households and male-headed households as disproportionately affected by climate-change. For example, studies in South Africa and Malawi show that male-headed households and female-headed households as experiencing differences in exposure and sensitivity to climate risks, with female heads more negatively impacted than male heads (Babagura, 2010; Kakota, 2011). Tibisegwa *et al* (2015), note that female-headed households in South Africa are more likely to suffer food insecurities due to weather-related crop failures than their male counterparts, resulting in reduced households consumption levels. Zakari *et al*, (2014) observe a similar pattern in Niger where female-headed households are more likely to experience food insecurity as a result of drought and flooding related crop losses. Again, in Malawi, female-headed households are also twice more likely than male headed households to report reductions in the number of meals consumed as an adaptation strategy in response to climate shocks (Kakota *et al*, 2011). Hence, and with no doubt, female-headed households are more sensitive to climate-change than male-headed households.

Female-headed households tend to be limited in adaptation options. For example, in the event of a drought, male headed households are more likely to take up off-farm opportunities. Options limited to men include temporary migration. In most cases, women remain behind resorting to low paying jobs due to commitments to fulfil social caring roles (Buvinic and Gupta, 1997). For example, in Ghana following weather-induced food insecurities, female heads have been reported to remain in the villages selling forest products and vegetables while male heads reported migrating to neighbouring areas in search of jobs (Alhassan *et al*, 2019).

Female headed households are also constrained in adapting to climate-induced food insecurities in several ways. They lack access to essential services necessary in addressing climate-induced food insecurities. These include formal credit, extension services and information on weather and climate-change (Tibesigwa *et al,* 2015). For instance, Alhassan *et al* (2018) in a study on smallholder farming households in Ghana, observed that female heads reported less access to formal credit and agricultural extension services leaving them dependent on relatives, friends and community savings groups for credit. Men in Senegal and Uganda also tend to have access to better weather information than women (Twyman, *et al*, 2014).

It is also typical that female heads are least likely to adapt to agricultural technology for improved households food security and or in response to climate-change and variability (Alhasan, 2019). For example, in Ghana and Uganda, male farmers are more likely to own agricultural tools and livestock (Doss *et al*, 2012). Whilst in Kenya, female farmers are substantially more likely to manually till fields, rather than use animals or tractors (Wanjiku *et al*, 2007). In Ethiopia and Cameron, female heads are observed as least likely to adopt new crop varieties and use fertilizer in response to weather changes due to lack of capital (Deressa *et al*, 2009; Gebrehiwot *et al*, 2013). Moreso, Alhasan (2019) notes low proportions of female heads in Ghana who adopt improved agricultural practices such as water and soil conservation, as well as ridging in response to weather-related food insecurities. Hence, adaptive capacity and mitigative options for female heads remain lower, exposing them to increased vulnerability to weather-related food insecurities (Lambrou and Piana, 2006; Carr, 2008; Eriksen and Silva, 2009; Tibisegwa, 2015; Alhasan, 2019).

Zimbabwe records large proportions (40%) of female-headed households residing in rural areas (Agritex 2002) with the majority (nearly three quarters) of them living below the national poverty datum line (Horrel & Krishnan, 2006). These are reported to experience challenges in financing agricultural activity, making them highly susceptible to households food insecurity (Nyikahadzoi *et al*, 2012). The food insecurity situation will likely worsen in the face of climate-change (Brown, 2012). Despite all this, and Zimbabwe's continued exposure to climate-related shocks, there remains limited literature on how female-headed households are coping with climate-change-induced food insecurities.

There exists a knowledge gap influenced by ommissions in most climate-change and social impact studies that pay attention to specifically addressing female-headed issues. Instead, most studies on climate-change and related social impact have adopted a more generalised approach to covering broadly rural livelihoods or agricultural activities. Examples include climate-change social impact studies by Brown *et al* (2012), Mutekwa (2015), and Bhatasara (2019) whose focus was solely on rural livelihoods and or smallholder agriculture activities. Whilst Musiyiwa (2014), and Gusta (2017) incorporated a gender lens in their studies, these remained anchored within the livelihoods framework, already reflecting limited to no coverage in research studies on climate-change and related impact on food security within female-headed households. A scenario that implies female-headed households may continue to encounter uncaptured difficulties in coping with climate-induced food insecurities as stated by Alhasan *et al*, (2019) and Tibesigwa *et al* (2015). Hence, the importance of bridging this gap through the application of conscious efforts in climate-change research to understanding the present circumstances of female-headed households. An evidence-based process that facilitates addressing several systemic constraints to achieving household food security and equitable access to resources within female-headed households through the institution of relevant policies and programmes at national, regional and international levels.

This study uses an in-depth approach that seeks to understand the effects and responses to climate-change on food security within the female-headed households. We use a case study research design of Buhera District with a female-headed households population of 41% (Zimstat, 2012). The study draws from the social action group of theories, particularly the action-oriented theory of adaptation as propounded by Klaus *et al* (2011). The action-oriented theory is used to analyse interrelatedness of the different elements that make-up human response systems following the change. The elements include the stimulus, exposure unit, receptor, operator and means of actions. The strength of the theory is in its ability to providing a holistic approach in analysing how humans respond to changing environments. In this analysis, food security means that people have access to sufficient, safe, and nutritious food that meets their food preferences and dietary needs for an active and healthy life.

Study Area

The study area is in Manicaland Province which generally houses majority female heads of around 41.8% in comparison to a national average of 35% (Zimstat, 2012). The area falls in Agro-Ecological Natural Region V of Zimbabwe which occupies low land area below sea-level 500 metres and is mainly arid and is characterised by erratic rainfall below 450mm per annum. The area is also marked by little irrigation infrastructure development and experiences recurrent crop-failure and food shortages. The region is suitable for extensive production and game-ranching (Anderson *et. al*, 1993). Hence, the combination of such agroecological and socio-demographic characteristics makes it best suited to understand how changes in climatic conditions are likely to worsen the social conditions of female-headed households as a vulnerable group. Figure 1, provides a site map of the study site.

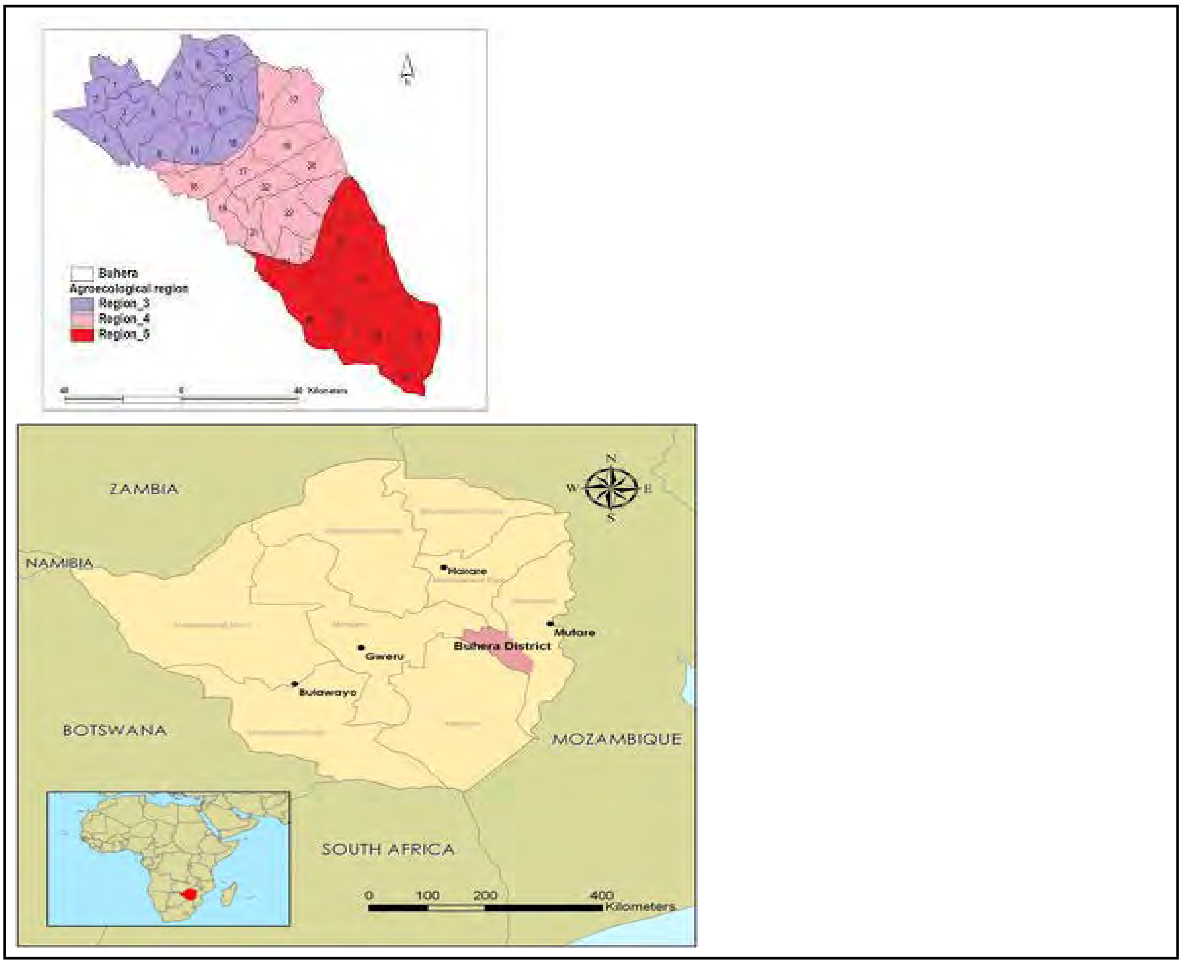

Figure 1: Study Site Map Buhera District Ward 30 Source:

RESEARCH METHODOLOGY

The study adopted a qualitative research methodology in which in-depth households interviews, focus group discussions and key informant interviews were used to collect data. Trend analysis was used to plot changes in the availability of different food baskets (carbohydrates, protein, and vitamins), as well as to capture the impact of changes in rainfall patterns on households food security. Focus group discussions with both young and elderly heads of households were conducted in the ward to capture experiences of the different demographic groups. Selection of participants for the focus group discussions was purposive to ensure the inclusion of persons with interests and knowledge deemed relevant to the research issues. Participants in focus group discussions were asked to list common foods in their households which were used to come up with a food classification list of different food groups. The participants in focus groups were then asked to draw a horizontal line on a flip chart based on different food groups common in female-headed households and marked times from 1970 to 2019. The participants were then asked to plot changes over time of the different types of food from their own production. The female heads of households were also asked to list the different coping strategies and show how their use was churning overtime. The researchers undertook some in-depth interviews with 10 female-headed households to capture the experiences of the female head in responding to weather-induced food insecurities.

Information from focus group discussions and in-depth interviews were then corroborated with seven key informants namely; ward-based councillors, agricultural extension officer, two representatives of the provincial and district administrative offices, the environment management district officer, and a representative from a non-governmental organization operating in the area. Key informant interviews were meant to generate expert knowledge on how female-headed households were coping with effects of climate-change on households food security and the challenges that they faced based on the expert's day-to-day interactions with this group including support programmes provided.

RESEARCH FINDINGS

Socio-demographic Characteristics of Participants

The primary respondents for the study were female-headed households age 18 years and above. Whilst their age groups and circumstances surrounding female headship varied, the majority comprised those in late middle age and the elderly of widows. Most of the elderly female heads had attained at least some form of primary level education. None of the female-headed households reported having gone through tertiary education. The household sizes ranged from three (3) to seven (7) members with most households reporting in care of at least 1 or more orphaned children. They reported subsistence farming as the main source of livelihood with sorghum as the main cereal crop grown by the majority.

Evidence of climate-change

Analysed data from Focus Group Discussions, shows that female heads have experienced gradual changes in weather patterns during the period 1970-2019. Results in Figure 2, show gradual increases in the occurrence of droughts throughout the reference period, from one drought year in the 1970s through two drought years in the 1990s increasing to 4 drought years post-2010 period. The presence of floods also becomes evident post year 2000, a phenomenon the elderly said did not occur in the 1970s, 1980s and 1990s.

Key changes in climatic patterns over the period under review can be explained in five categories. Firstly, they noted marked changes in dates of the year for the onset of first rains. They narrated that in the 1970s the area used to receive the first rains of the agricultural season early November. This pattern has since changed since the last fifteen or so years. Secondly, participants also noted an increase in the length of dry spells during the rainy season. They mentioned that in the period 1970 to 2000, dry spells would stretch from early January to late January. This has since changed as the dry spells now stretch into early March, witnessing prolonged dry spells of more than 21 days in January. Thirdly, female heads also said that they are witnessing gradual reductions in the amount of rainfall received.

They noted a decrease in the amounts of first rains received as evidence by low soil moisture-retention following rain days during the rainy season. Fourthly, they also mention that during the last ten years they are witnessing a new phenomenon where the first rains are accompanied by very strong winds which they claim disturb the distribution of rains in the area. Fifthly, they also mentioned that for the past 6 years they have witnessed the disappearance of winter rain known as '*bumharutsva*' which used to mark land preparation and would usually come in the period end of July and early August.

Lastly, female heads also mentioned witnessing an increase in the frequency of droughts and floods. According to the research participants, the period 2010 to 2019 had the highest frequency of droughts. For purposes of this study, the term drought was used about farming season characterized by poor harvests following a short rain season marked by prolonged dry spells of more than 21 days and or low rainfall. The researchers asked the female heads to show years when the area experienced droughts and floods between 1970 and 2019. Figure 2, provides a summary of droughts and floods as explained by female-headed households during focus group discussions.

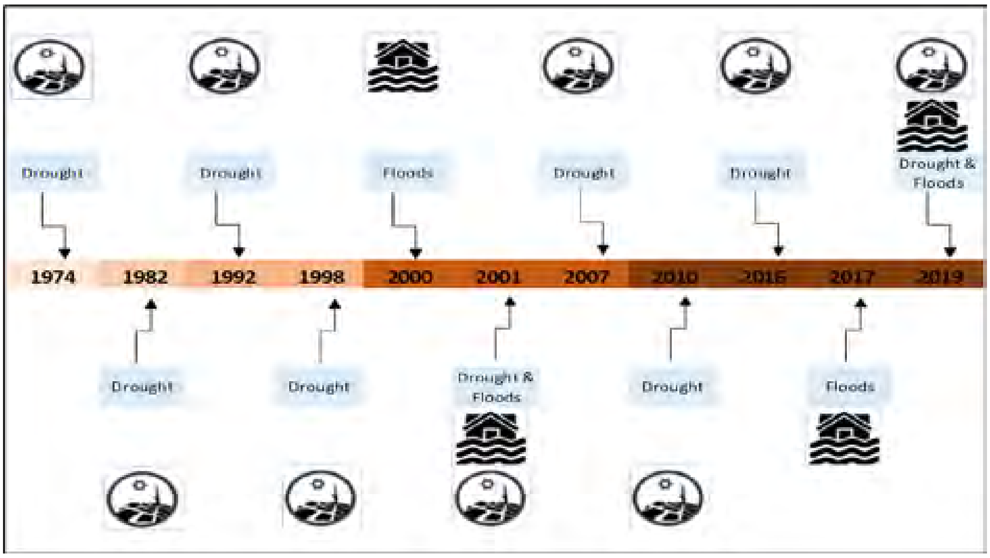

Figure 2: Droughts and Floods Occurance in Buhera District- Ward 30 From 1970 to 2019

Overaly, findings from the study reflect evidence of climate-change. This is described by participants in terms of changes in weather patterns ranging from shifts in onset of first rains, amounts of rainfall received, length of dry spell and increases in the incidence of floods and droughts in the post-2000 period.

Effects of Climate-change on Food Security in Female-Headed Households.

Effects of climate-change on consumption patterns

Female-headed households report several negative effects of climate-change in households consumption patterns since the period 1970s, particularly the number of meals consumed in a household due to declined agricultural productivity.
Number of meals per day during drought and non-drought years

The term meal was confined to a serving of food prepared for the households to consume at designated times of the day. Under normal situations, a household should at least consume three meals, which are breakfast, lunch and supper. However, weather-related shocks such as droughts and floods negatively

affect households food security as a result of poor production. Based on respondents' feedback, many households are forced to have a single meal when there is a drought and two meals per day since the onset in changes in climatic conditions and weather patterns.
An elderly woman who was part of one of the focus group discussions had this to say:

'Kare taitoziva kuti munhu wese unongodya rutatu pazuva. Kuzotanga kwaita kushaika kwemvura umm takuchingoziva shiri kadzi dzinodya kairi pazuva. Kukazoita drought panokonza semakore kwatotodya kamwe. Vane vechikoro vanongopihwa chikafu kuchikoro kwakuzodya mese kamweko manheru'- [Previously it was common that individuals would have three meals a day. However, following the increases in reduced rainfall female heads now resort to two meals a day. During drought years it becomes difficult and they resort to one meal per day. School children will depend on school-feeding programmes with families usually having their one meal in the evening].

Climate-change and Months of Food Adequacy from Own Produce.
According to informants, a household is expected to produce enough food for consumption until the next harvest. Results from Figure 3, show perceived changes in the number of months that maize, pearl millet and sorghum would last after a harvest within female-headed households from 1970 to 2019. Results in Figure 3 show that the major sources of cereal are millet and sorghum.

Effects of climate-change on households's production of cereal

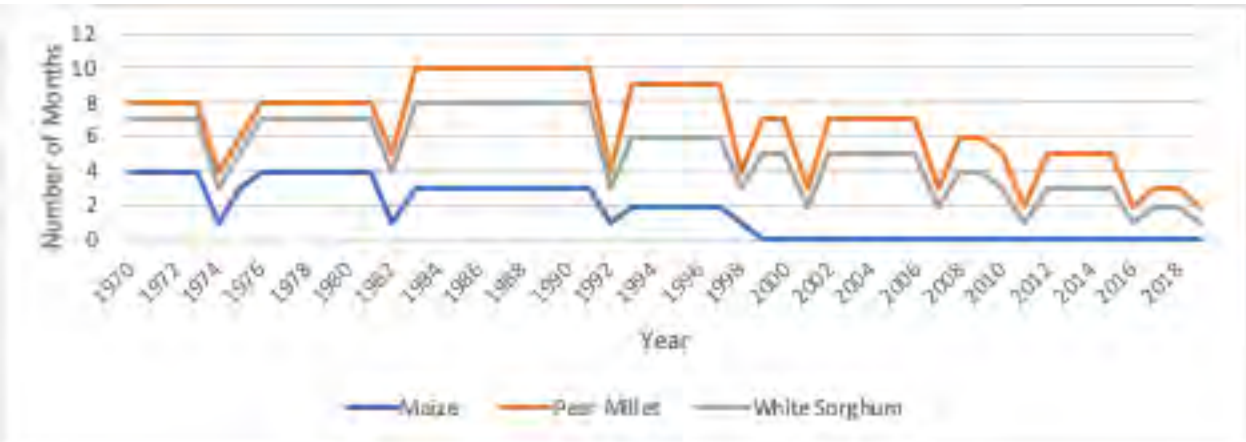

Figure 3: Months of Self Provision through Own Production of Cereal Source: Primary Data

In 1970, some households had taken up maize production for households consumption. The results show a gradual decline in months of households self-provisioning of maize from the 1970s period. Female informants explained that it was common practice to grow maize though it is not drought-tolerant like any other households in the periods 1970s to 1990s. The crop was grown on wetlands or in small gardens where women would use water from shallow wells to irrigate the crop. Female households reported that it was possible under normal years to harvest maize that would provide at least three months of household's supply in the years between 1970 and 1999. In 2000, the contribution of maize to female households cereal requirement declined. According to the female households heads that attended the focus group discussion, growing maize ceased following continued drying of the wetlands and garden wells due to the gradual decline in rainfall, the persistence of prolonged dry spells and increased incidences of droughts post year 2000. Although some households are still growing maize in Bonde Communal Irrigation Scheme, some female heads reported that not all of them have a plot in the irrigation scheme as some of them lost their land to their husbands' families after the deaths of their husbands. Others complained that they were never allocated land in the irrigation scheme because the registration process favoured those able to raise subscriptions and or rental fees required to use plots in the irrigation schemes. Also reported was that very few female-headed households had the capacity to raise the required money to be able to utilize all the allocated land in the irrigation scheme. The majority were left out because they lacked the required capital.

Female-headed households report continued growing of drought-tolerant crops such as pearl millet and sorghum as sources of cereal (Fig 3). Female heads attributed the gradual changes for all the three crops to changes in climatic periods and shifts in weather patterns, especially towards extreme aridity. Besides gradual changes in climate and weather patterns, female heads reported less and less land being cultivated, even for growing small grains, despite their importance in ensuring households food security. Reported specific reasons for cultivating smaller acreages included insufficient draught power and money to purchase inputs; poor quality land and lack of labour. Female heads reported that cultivating small grains is labour- intensive, especially that for weeding which is done at least twice before harvest, crops protection from wildlife and food-processing (which include pounding and roasting before taking it to the grinding mill). The respondents also reported that female-headed households depend on family labour while some male-heads can pay for hired labour, hence capable of complementing family labour. Informants also attributed the poor yields of sorghum and pearl millet to use of the retained seed, a common practice among female heads unable to purchase improved seed varieties. Whilst female heads have the option of depending on drought-tolerant small grains which should help overcome weather-induced food insecurities as threatened by climate-change, they are currently faced with several limitations resulting in failure to maintain adequate cereal sources through such crops (Fig 3).

Effects of climate-change on households' access to protein giving foods

Analysed data from FGDs highlight that protein is largely obtained from livestock, fishing and hunting of small animals such as rodents, insects such as *"harurwa"* or stink bug (*Encosternum delegorguei*) etc. According to the participants during the focus group discussion, very few households with a migrant get a fresh supply of beef, only when the migrant returns home Figure 4**,** shows the results of the trends analysis on the number of days a household was able to provide its source of protein.

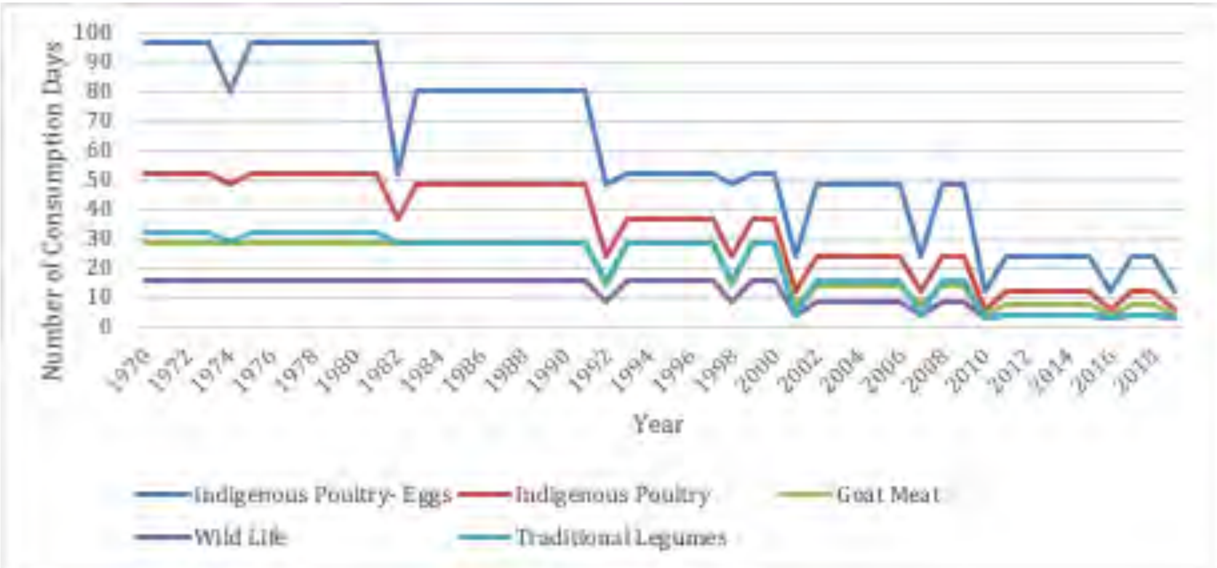

Figure 4:Trends-Annual Days in Consumption of Protein Food Sources

Source: Primary Data

From 1970 to date (Fig 4), there has been a significant decline in the number of days that a household consumes protein-giving foods within female-headed households. These include indigenous poultry, particularly traditional chickens (and their products-eggs), goat meat, traditional legumes- bambaranuts, cowpeas, groundnuts and wildlife – fish and Aquila birds. During droughts, there were years marked with severe declines in the consumption of all protein-giving foods as shown by deeps spread through different years in results. Female heads attributed both the gradual decline and increased incidences in the decline of food sources post year 2000 owing to the gradual changes in climatic condition and weather pattern that was characterized by a high frequency of droughts.

A significant decline was reported in the consumption of indigenous poultry, particularly traditional chickens within female-headed households from 52 days per annum (once every week) to 12 days of consumption per annum (once every month) from 1970 to 2019 respectively (Fig 4). A similar trend is observed with the consumption of chicken eggs. Female heads reported a continued decline in stock feed and water for livestock following continued changes in the weather pattern and climatic conditions from 1970 to date. They also reported that livestock is becoming more susceptible to diseases due to weakened immune systems. This scenario is reducing animal productivity and inherently resulting in decreased households protein-consumption. They mentioned Newcastle disease as one of the diseases that has become more prevalent following increased incidences of food and water shortages associated with persistent droughts in the period 2010 to 2019. Female heads again reported lack of money to purchase vaccines, worsening their plight as it results in depleted flocks.

Study results also show a decline in the consumption of goat meat (Fig 4). Informants highlighted that while goats are not affected by climate-change, female-headed households do not take goat meat. Instead, goats like other small livestock such as chickens used to self-insure against drought or bad seasons. When faced with food shortages, small livestock is sold to buy food. Female heads opt to preserve these for sale or exchange for food during pick lean seasons.

There has also been a decline in the consumption of traditional legumes as a major source of protein within female-headed households (Fig 4). The list included Bambara nuts, groundnuts and cowpeas which are usually prepared as a meal for a household. Sugar beans were excluded as they are non-drought tolerant and are grown in irrigation schemes which most female heads have limited to no access. Informants attributed the gradual decline in consumption of legume-based protein source of food to continued reduced yields. This is following declines in both the amount of rain and the number of annual rain days. They mentioned the delays in the onset of first rains coupled with labour constraints, lack of draft power, and overburdening social caring roles limiting their ability to cultivate large areas. They also mentioned lack of income to purchase improved drought-tolerant high-yielding seed varieties and fertilizers as other contributory factors to reduced yields, resulting in declined annual days of consumption of the specified protein source.

Also reported during FGDs is a decline in consumption of wildlife post the year 2000 within female-headed households (Fig 4). The reported decline is also associated with the drying of wetlands and major water bodies particularly the Save River where sugar cane and wheat would ordinarily be cultivated. The cultivated land was a major attraction of the Quelea birds, an alternative source of protein within female headed households. The drying up of wetlands also reduced sources of fish which was a major source protein. One elderly woman who participated in a focus group discussion had this to say:

'Kuzongowanda kwaita mwaka isinganayi mvura zvinaana musosera, nezvingozha zvakutoitawo zvishoma. Taisimbozviona nguwa yekuti zvirimwa

zvakuibva mumaminda nekumapeto enzizi kuna SAVE kwairimwa nzimbe nemungoza asi nguwa dzinoidzii hakuchina. Segore rinoiri hapana. Hapeno tinopona nei.'

[Ever since we started experiencing frequent droughts wild bird and vegetables have also started decreasing. They used to be accessed along the riverbanks in the sugarcane and sorghum plantations. Especially this year there are not available. We are therefore not sure of how we will survive]" (Buhera, 21 June 2019)

Thus, results in Figure 4, depict climate-change as negatively affecting overall access to protein food sources within female-headed households.

Effects of climate-change on households' access to Vitamin-rich food

Vegetables are major sources of vitamin-rich foods. Figure 5**,** shows the trends analysis of the estimated number of months in a year that they have an adequate supply of vegetables and by type of the vegetable. The reference period was 1970 to 2019.

Figure 5:Trends in Monts of Self Sufficiency in Vitamin Rich Foods

Source Primary Data

Exotic vegetables, indigenous vegetables, wild vegetables and wild fruits formed common sources of vitamins within female-headed households. Results in Figure 5, show a steady decline in months of self-sufficiency from exotic leafy vegetables which include rape and, chomolia since the 1990s. The same results show a gradual increase in months of self-sufficiency in indigenous vegetables, wild vegetables and wild fruits since the 1990s, a period associated with a decline in months of self-sufficiency on exotic vegetables. Indigenous vegetables included cowpea and pumpkin leaves, while wild vegetables included species which are not cultivated and usually grow in the rainy season namely "*mowa, musuna, mutsine"*. Wild fruits included "*mawuyu* and *masawu*" which are common indigenous fruits that grow in the forests in Ward 30 Buhera District. Female heads narrated several reasons to explain the trends in relation to changing weather patterns and climatic conditions.

Female heads attributed the steady decline in months of self-sufficiency on exotic vegetables such as rape and chomolia as shown in Figure 4, to continued decreases in yields of water in shallow wells and rivers used in irrigating the vegetables following a decline in annual rainfall since the 1990s. They also note the emergence of short rainy seasons as contributing to fewer months of reliance on pumpkin leaves which thrive during the rainy season.

Results in Figure 4, show a gradual increase in months of self-provisioning on indigenous vegetables, particularly dried cowpea leaves, since the 1990s, a period that follows a decline in consumption of garden leafy exotic vegetables. Female heads note cowpeas as a drought-resistant crop which performs better in arid conditions thereby making it a suitable alternative source of vegetable for female heads who solely rely on rain-fed systems for food and income.

The relative importance of fresh and dried wild vegetables as relish "*mowa, musuna, mutsine"* also started in the 1990s as a substitute for exotic vegetables as shown in Figure 5. Previously these would be consumed only for their medicinal properties a trend that has since shifted to include reliance of these as relish. Female heads also note the decline in reliance on irrigated vegetables due to numerous systemic constraints such as lack of access to irrigation facilities, an aspect that had left them dependent on forest-based vegetables which they harvest in abundance during the rainy season and preserved through natural drying processes for use later in dry months of the year.

Results also show an increase in self-provisioning on wild fruits since the 1990s particularly "*mawuyu*" – **baobob fruit** which grows in abundance and is best suited in arid conditions (Fig 5). The fruit pulp is used to make porridge in drought years which in addition to vitamins contains carbohydrates. This finding signifies the importance of non-timber forestry products as an alternative source of vitamin in female-headed households.

Overally, the study highlights the importance of indigenous vegetables and fruits as alternative sources of vitamin-rich food in female-headed households. These, whilst dependent on rain fed systems are drought tolerant, thereby offering a much more noble alternative in circumstances where female heads face systemic constraints in adoption of climate-smart technologies for cultivation of exotic non-drought tolerant crops.

Response Strategies

The above analysis shows a downward trend in the availability of the food groups for female-headed households. Households heads were asked to list the different coping strategies that they use when they do not have enough food for the households. When female heads are faced with severe food shortage, they tend to sell assets and/or borrow food or income to purchase food. Female heads note an increase in depending on selling assets- goats and traditional chickens as a short term mechanism to deal with weather-induced food insecurities. Female heads indicated that they prefer smaller livestock such as goats, sheep and chickens because they are easy to sell when a household faces food shortages.

Surviving on in-kind assistance and remittances also forms one other coping strategy used by female heads. During the focus group discussions, it was reported that most of the households are receiving some remittances from a migrant working within the country or in other neighbouring countries such as Botswana and South Africa. However, they note a decline in frequency and source of remittances since the 1990s, becoming more pronounced post 2010 period, a trend they attribute to increased incidence of drought in the area. The latter makes it difficult for relatives and well-wishers in the same community to continue supporting female-headed households as they themselves also continue to face declined yields. On the other hand, children of female-headed households who migrated are reportedly finding it difficult to frequently remit and contribute significantly to households' incomes because they usually get low-paying informal jobs upon migrating. The set-up shows a situation that depicts overall weakening of the informal social safety net system in its ability to continue functioning as an alternative means to secure food for female-headed households in the face of climate-change.

Reliance on external support in the form of food-distribution handouts, cash transfers or input assistance programmes also forms part of coping strategies used in female-headed households. These services are provided by both government and non-governmental organizations through direct hand-out programmes targeted at vulnerable households or through food for work programmes which also provides an opportunity for patronage in the countryside. However, female heads mentioned reservations as they tend to be left out during the selection process. According to one key informant, the government's social protection schemes for the vulnerable started to go down in early 1990 as the government was trying to cut on recurrent expenditure affecting the extent to which female heads can rely on such services as an alternative response strategy. Additionally, female heads raised concern on the additional burden placed through participation in food for work programmes as they are already labour-constrained and are overburdened with social caring roles. They also note most food aid programmes have maintained a seasonal approach making it available only at certain times of the year (August to January). Yet, with shifts in weather patterns and continued increases in declined yields, most female heads will already have been 2 months into food insecurity status by time distributions start. In regards to input distributions, they mentioned the timing of distribution which comes way into farming season as limiting the effective use of such resources.

Diversification of livelihood sources through engaging in casual labour activities and participation in savings groups also forms part of the response mechanism to weather-induced food insecurities within female-headed households. However, the participants of FGDs observed that there was a decline in the use of casual labour as a coping strategy since the early 1990s. They note households used to sell their labour to better-off farmers, a practice has also started going down as the demand for labour to work in the fields declines following continued changes in weather patterns. They also noted most of the farmers as gradually shifting to use of labour-intensive techniques such as conservation agriculture. It must be observed that this method is unfavourable to women with persisting back problems due to numerous birth because it worsens their already precarious health.
Female heads also mentioned that they have adopted savings groups that are being promoted by some NGOs is also used as a coping strategy An approach rooted in the use of community-based social networks in generating a pool of resources and savings in the form of food or cash which they share at the end of some stipulated time frame helping poor households cope with persistent food shortages. The provisions of a loan facility within the concept also helps them respond to the emerging weather-induced food crisis.

DISCUSSION OF FINDINGS

Findings from the study reflect several ways in which climate-change is negatively affecting food security within female-headed households directly and indirectly through reduced crop-production or disruption of other subsistence means/systems used in accessing food. This results in reduced months of self-provisioning through own production of cereal produce. Further, it also results in decreases in annual days of consumption of protein food sources common within female-headed households and exotic sources of vitamins. On the other hand, dominance in the adoption of indigenous crops and resorting to non-timber forestry products as alternative food sources is registered.
Findings from the study reflect numerous ways in which climate-change, as evidenced by increased incidences of drought, mid-season dry spells, reduced amount of rainfall and late onset of rainfall to mark the farming season, has over the years (1970-2019) been affecting food security within female-headed households. This includes altering typical consumption patterns within female-headed households thereby reducing the number of meals consumed per day, changes in households' dietary needs, substituting desired foods for other uncommon food sources. As noted in this chapter, this is likely to compromise the health in female-headed households, especially those with young chil-

dren to look after. The probability of children suffering from diseases related to unbalanced diet is high among female-headed households. The situation is likely to increase the levels of malnutrition in female-headed households due to lack of access to good quality and nutritious foods.

It is also worth noting that in the face of the changes female heads resort to reliance on indigenous crops (sorghum, millet, cowpeas) and non-timber forestry products. This is precipitated partly by the failure of exotic crops and vegetables (maize, chomilia) to thrive, being drought intolerant.

Stevens (2007) notes a symbiotic relationship between bonding capital and households food insecurity in situations where smallholders work together to address challenges that arise in the wake of a drought. This study has shown shifts in the way social capital functions in providing a safety net for the female-headed households as the traditional approach of relying on bonding capital to secure food through borrowing, remittances and in-kind/material assistance is compromised. There is also an increase in reliance on community-based informal savings and loaning facilities as response strategies to weather-induced food insecurity within female-headed households both in the short and medium-term.

The promotion of climate-smart technologies such as conservation farming has not helped female-headed households. Firstly female-headed households do not have the labour required to adopt labour-intensive technologies such as conservation farming. Secondly, female-headed households cannot sell their labour to well off farmers who are also adopting conservation farming given that the technology is very strenuous particularly for the elderly women.

We also note that female-headed households have limited capacity to survive when faced with severe food shortages caused by droughts as other strategies are proving less reliable. The most common strategy is selling of small livestock such as goats, sheep and chickens which have traditionally been recognized as female-based assets to get money to buy food. Although goats and sheep are drought resistant livestock, an increase in adoption of small livestock is likely to threaten forested areas which are used as sources of forage.

The importance of social transfers in the form of food, cash and agricultural input handouts remains important as short-term social safety measure in helping the vulnerable to withstand the effects of climate-change on households' food security. The study notes the value of indigenous resources in the form of crops, livestock and non-timber forestry products in providing means to accessing food following weather-induced food insecurities.

CONCLUSION

In conclusion, it can be noted that female heads remain highly sensitive to climate-change-induced food insecurities as they lack the necessary means and resources to diversify income and food sources, including the adoption of climate-smart practices. Gender norms constrained socio-economic background and institutional barriers make their situation worse. Use of indigenous resource systems in responding to weather-induced food insecurities remain key within female heads. This promotes the need to develop policies that speak to addressing challenges met in diversifying means of securing food, adoption of climate-smart practices and effective use of social transfer programmes meant for the vulnerable who include female-headed households.

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CHAPTER **06**

IMPACT OF CLIMATE-CHANGE ON THE LIVELIHOODS ACTIVITIES OF FORMER COMMERCIAL FARM WORKERS IN MAZOWE SOUTH CONSTITUENCY, ZIMBABWE

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Source: https://www.scidev.net/sub-saharan-africa/wp-content.jpg

ABSTRACT
This study sought to explore the impact of climate-change on the livelihoods strategies of former commercial farm workers in Mazowe District, Mashonaland Central Province in Zimbabwe. A Mixed Methods Research design was used as the strategy of inquiry. Availability sampling approach was used in which 210 former commercial farmworker household-heads were selected. Data was collected through focus group discussions and a self-administered questionnaire. Analysed data shows climate-change is worsening key livelihoods strategies of former commercial farmworkers. Key livelihoods strategies affected by climate-change include menial jobs, gardening, gold- panning, brick-moulding, trading in agricultural and non-agricultural products, water- vending and livestock-rearing. The study recommends that the best way of addressing the plight of these landless rural people in the face of climate-change is through strengthening of non-agricultural livelihoods and allocating land to former farmworkers so that sustainable adaptive livelihoods can be implemented.

Keywords: Climate-change, former commercial farm workers, livelihoods, resilience strategy

INTRODUCTION

Climate-change is ravaging the entire world with serious ramifications being experienced in the global south due to weak disaster mitigation and management structures. Projections attest to increased extreme weather conditions as a result of climate-change (Intergovernmental Panel on Climate-Change, 2007). Severe impact of climate-change is felt by the world's poorest people (Dominelli, 2011). Climate-change affects a number of sustainable development issues such as health, education, employment, food security, housing and gender equality (Sugirtha & Little Flower, 2015). Africa is one of the most vulnerable regions due to poverty and limited capacity to cope. Climate-change continues to weaken livelihoods and national incomes of the region due to over-reliance on rain-fed agriculture (Chagutah, 2010).

Effective mitigation of climate-change is necessary to reduce its adverse impact on landless rural communities. Recent agricultural productivity has been on the decrease due to several factors among them, climate-change (United Nations Development Programme [UNDP], 2016). UNDP (2016) further notes that agriculture in Zimbabwe is particularly vulnerable to disasters and drought which occur regularly and are expected to increase in the coming years due to climate-change. Zimbabwe is also regularly affected by violent storms which destroy infrastructure, crops and sometimes may result in loss of lives. Diseases such as tuberculosis, malaria and cholera are exacerbated by HIV and climate-change (UNDP, 2016). Erratic rains, drought, mid-season dry spells combine to cause crop and livestock price changes. High prices become a threat to livelihoods as most people will fail to afford them. Many former farmworkers who continue to live on the farms are vulnerable, subject to precarious livelihoods, poor working conditions and limited access to assets (Scoones *et al*, 2019).

Zimbabwe is in a precarious situation due to climate-change (Mango *et al*, 2014; Karfakis, Lipper & Smulders, 2015). This is evidenced by the occurrence of severe and frequent droughts, tropical cyclone, temperature changes, shifting in the onset of the rain season and many other events. Droughts affect rain-fed agricultural production as well as water supply for domestic, industrial and agricultural use (Kaseke, 2012). The vulnerability of rural households to climate risk in Zimbabwe may be linked closely to socio-economic conditions, which correlate with the people's adaptive capacity (Nyahunda & Tirivangasi, 2019). Most people in rural Zimbabwe live in poverty and hence cannot cope with the dire effects of climate-change.

Zimbabwe is battling with economic stagnation which was triggered by among other things international isolation after the fast track land reform programme. According to Changutah (2010), the Fast Track Land Reform Programme (FTLRP) coincided with temperature increases, erratic rainfall patterns and erratic droughts emanating from climate-change. According to Mpambela and Mabvurira (2017), people are not affected by climate-change in the same way but variations come with geographical location, culture, socio-economic and political factors. The poor rural people suffer more than their urban counterparts. Poverty in Zimbabwe is more pronounced in rural areas (76%) compared to urban areas (38%) (ZimVac, 2014). With the catastrophic impact of climate-change, eradication of hunger and ensuring food security for all becomes a daunting task.

Most former commercial farm workers in Zimbabwe were not allocated land during the fast track land reform programme. Most of them continue to stay on the farming compounds but without agricultural land. They rely on menial jobs on the farms and other illegal activities like gold-panning and fishing for survival. Brown *et al* (2012) argue that the economy and livelihoods of poorest people in Zimbabwe are highly dependent on rain-fed agriculture. It becomes imperative to look at how the landless rural people in agro-based regions like Mazowe District fare with the impact of climate-change. In Mazowe South Constituency, people and ecosystems are vulnerable to decreasing and more variable precipitation due to climate-change. One of the most significant and broadly impacting effects of climate variability in Mazowe District is changes in water levels in Mazowe Dam (Kaseke, 2012).

During the colonial era, farm labour in Zimbabwe came from Malawi, Zambia and Mozambique (Scoones *et al*, 2019) and the working conditions were generally poor. These workers knew little beyond the farms and there were restrictions and off-farm work, even small gardening, was prohibited (Scoones *et al,* 2019). Most foreign recruited workers were stateless as they did not have identity documents, citizenship rights, and had lost contact with their families. Several generations of families had lived on farms often moving from one farm to the other depending on the availability of employment. The year 2000 marked a new era as the FTLRP came into effect.

Farmworkers were either chased away, joined the invasions or were just left on the compounds. The new small farmers and commercial farmers who gained access to this land had little capacity to absorb all the jobless farmworkers. Mabvurira *et al* (2012) note that with the take-over of the farms, access to housing has become insecure to most, some former farmworkers were even evicted from farm compound houses. Though scholars do not agree on the proportion of farmworkers who got land, it varies from 2 to 15% (Scoones *et al*, 2019). Mabvurira *et al* (2012) also reported that extensive food shortages among former farmworkers represent one theatrical effect of their wobbly social situation.

According to Alexander (2006), farmworkers have become an itinerant, poor and unstable class, almost destitute, and constantly drifting. A significant number of former farmworkers is *in situ*- staying on the compounds but not working. Those who continue to work on the farms have no formal salaried jobs. As noted by Magaramombe (2001) low levels of education among former commercial farm workers make it difficult for them to secure formal employment elsewhere. Most of them have resorted to activities like vegetable gardening, hunting, vending and gold-panning as coping mechanisms (Sachikonye, 2003; Mabvurira *et al*, 2012). This study, therefore, sought to examine the impact of climate-change on in *situ* displaced former farmworkers in Mazowe South Constituency.

Impact of climate-change on rural areas

Rural people are believed to be particularly vulnerable to climate-change. Their vulnerability is not attributed to climate-change only but is also a combination of social, economic and environmental factors that interact with it (Turpie & Visser, 2013). According to Brown *et al* (2012), persistent drought in Zimbabwe has seriously strained both surface and underground water and this has resulted in the country's deteriorating water supply. A significant proportion of the rural population in Zimbabwe lack improved water supply. Mpambela and Mabvurira, (2017) note that the rural people in Zimbabwe are the hardest hit as they mainly rely on agriculture for their survival due to skyrocketing levels of unemployment and lack of adequate resources and income to supplement their food security. Porter et al (2014) report an increase in food prices due to low agriculture productivity and a decline in yields.

According to Nyahunda and Tirivangasi (2019), Zimbabwe's rural community has been negatively affected by the impacts of climate-change. This can be evidenced by the increase in unreliable rainfall patterns, resulting in nationwide flash floods and droughts. This has left communities that rely on farming outputs at greater risk because climate-change diminishes the prospects of having a great yield every year.

Climate-change has a severe impact on the health of human beings. Collesto *et al* (2009) argue that it is the biggest public health threat of the century. There is overwhelming evidence that climate-change will affect human health through the rise in frequency of floods, storms, droughts, veld fires, changes in the range of infectious vector, diarrhoeal diseases and water-borne diseases (Brown *et al*, 2012). Climate-change causes headaches and in severe cases stroke and death (Mpambela & Mabvurira, 2017). According to Brown *et al* (2012), extreme weather conditions like flooding have the potential to cross-contaminate water and sanitation systems thereby heightening the risk of waterborne diseases. The effects of climate-change have been visible in rural Zimbabwe, with some communities facing food insecurity, water scarcity and loss of livestock (Nyahunda & Tirivangasi, 2019).

THEORETICAL FRAMEWORK

This study was guided by the social-ecological resilience theory. According to Adger (2006), social-ecological systems theory is premised on the belief that human beings often referred as subsystems, their activities which form part of their livelihoods and the natural environment (the ecological subsystem) directly or indirectly interact and are interdependently integrated. The IPCC (2007) defined resilience as a process with which social and ecological subsystems adapt to disturbing circumstances while bouncing back to the normal way of functioning. Gunderson and Holling (2002) view resilience as the ability of a system to reorganise itself and absorb the stress through sustainability and development.

The social-ecological resilience theory is centred on that stressful and disturbing circumstances are common to any system. Adaptation to the disturbances should holistically focus on the advantages and opportunities that may develop out of the prevailing challenges (Nelson, Adger & Brown**.** 2007; Gallopin, 2006). For a social-ecological system to be considered as a resilient entity, it must have the capacity to withstand disturbances (climate-change) whilst maintaining its normal way of functioning and identity. In other words, resilient systems possess the capability to; adapt to climatic induced shocks and stresses, to discover and reorganise and to identify opportunities, learn and adapt (Gunderson & Holling, 2002). According to Seixas and Berkes (2003), both social and ecological systems are affected by climate-change as integrated systems. In these, the human activities are linked to the ecosystem which people directly or indirectly interact with. There are key indicators of social resilience, which include: diversity of income sources, the level of education, participation in decision-making, ability to self-organize, and access to credit (Tompkins & Adger, 2004). Landless former commercial farmworkers are a subsystem haunted by the negative effects of climate-change.

STUDY METHODOLOGY AND RESEARCH METHODS

Study Area

The study was carried out in Mazowe South Constituency in Mazowe District, Mashonaland Central Province in Zimbabwe. Mazowe South Constituency is in agro-ecological Natural Region II which is good for crop-production. Most of the farms in Mazowe South Constituency have been subdivided into small plots for resettlement purposes. The area has both smallholder farmers as well as large scale farms. The main commercial crops grown are maize and soya bean. There are several farming compounds in the area most of which are inhabited by landless citizens most of whom trace their ancestry to Malawi, Zambia or Mozambique.

The study adopted a Mixed Methods Research Methodology in which qualitative and quantitative data where triangulated. The study targeted households of former commercial farm workers residing in farming compounds in Mazowe South Constituency. Data were collected through self-administered questionnaires and focus group discussions. A sample of 210 former farmworker households heads was selected using the convenience sampling technique. The researchers visited various farm compound homesteads in the study area and those household heads who were available and consented became the study respondents. Data collection started with the administration of a questionnaire, followed by focus group discussions. The discussants were identified during the questionnaire administration. Three focus group discussions each with 9 respondents were conducted with the former commercial farmworker household-heads. Data was analysed using excel spreadsheets and thematic content analysis. Research ethics of voluntary participation, informed consent and confidentiality were observed throughout data collection and reporting. Consent was verbally sought from the respondents

RESULTS

Socio-economic characteristics of respondents

A sample of 210 household-heads participated in the study, and of these 78 were females while 132 were males. They ranged in age from 27 to 68 years with a mean age of 48 years. The respondents engaged in various livelihood activities and it was common to find one participant engaging in multiple activities as shown in Table 1 below:

Table 1: Livelihoods activities of former commercial farmworker

Activity	**MALE**		**FEMALE**		**n**	**%**
	n	*%*	*n*	*%*		
Casual employment on farms	93	44.28	70	33.33	**163**	**77.61**
Permanent full time employment on farms	21	10.00	16	7.61	**37**	**17.61**
Employment on non-agricultural activities	5	2.38	1	0.47	**6**	**2.85**
Gardening	38	18.09	17	8.09	**55**	**26.18**
Gold panning	40	19.04	3	1.42	**43**	**20.46**
Water vending to gold panners	2	0.95	37	17.61	**39**	**18.56**
Buying and selling of agricultural products	18	8.57	7	3.33	**25**	**11.90**
Trading in non agricultural commodities	47	22.38	46	21.90	**93**	**44.28**
Brick moulding	39	18.57	16	7.61	**55**	**26.18**
Farming on rented/ state land	27	12.85	30	14.28	**57**	**27.13**
Livestock rearing	7	3.33	8	3.80	**15**	**7.13**

As shown in Table 1 above, former commercial farmworker engaged in varied livelihood activities including being engaged by the resettled farmers thought generally on a casual (when need arise) basis. The respondents were generally poor with a mean monthly income of ZWL149 (RTGS[5] dollars). All the respondents stayed in farming compounds and none of them was allocated land during the FTLRP.

Impact of climate-change on former commercial farm workers in Mazowe South constituency

Results of the study showed that climate-change affected a number of life aspects of former commercial farmworkers. Climate-change was found to be threatening the livelihood activities of former farmworkers in a number of ways. Due to their landlessness and lack of reliable sources of livelihoods, climate-change was found to be hammering on already poor rural dwellers. All the 210 respondents confirmed that climate-change was negatively affecting their livelihood activities.

5 An electronic Zimbabwean currency

Casual and permanent employment
As shown in Table 1, 77.61% and 17.61% of the respondents worked as casual labourers and permanent employees on the farms respectively. Casual labourers were defined as those who were engaged by the new farmers to perform various tasks when need arose while permanent employees were defined as those who were employed for more than a year and without a known date of termination of the contract. The former farmworker households indicated that they relied on menial jobs, working on other people's fields doing activities such as planting, weeding, spraying crops, harvesting and shelling maize. These menial activities were heavily influenced by changes in climate, especially during drought or lean season periods. The 2018/2019 rain season was cited as one such lean season. The respondents reported that during lean seasons they would hardly get the menial jobs and if they did get them, their remuneration was very low. In a good season, they would work for US$ 3 per day in the fields but during the 2019 harvesting period they were working for a daily income of US$ 1. They attributed the low income to low yields due to low rainfall received. They indicated that the field owners complained that they were not in a position to pay more due to poor yield.

Very few respondents (n=37) reported being employed on a permanent basis by the resettled farmers. All of them worked on farms assuming various posts ranging from tractor driving, security guards and general farm labourers. Those who were formally employed reported that changes in rainfall patterns from season to season had an impact on their incomes. Their wages always fall during drought years. It was also found that lean/drought seasons had an impact on the amount of work that the labourers engaged in. Mid-season droughts meant more work for the employees as they sometimes had to do irrigation. A drought year also meant that some employees had to be temporarily laid off work.

Too much rainfall was also reported to cost the employees. A case in point was the 2017/2018 season in which the area received excessive rainfall characterised by hailstorms. The storms destroyed tobacco and 5 (2.38%) of the respondents reported that their incomes were severely affected. Wages of the employees relied on the farmers returning good profits. Whenever the climate affected yield, the employees had challenges being paid their wages. Both the casual and permanently employed respondents indicated that their income was reduced by a mean approximate figure of 40% during a drought year.

Gardening
All the 210 respondents reported that they did gardening mainly for own consumption and, a few (n=55) reported that they were running garden projects for commercial purpose and they sold the produce to walk-in clients or vendors at Glendale business centre. More men than women, 18.09% and 8.09% reported running garden projects for commercial purposes, respectively. The respondents reported that their projects were affected during lean seasons. Most of the respondents (87%) were using river water for irrigating their gardens while 13% used underground water and when the water levels went low, it was difficult for them. This was confirmed by the following statements;

> *This year we did not receive good rains. As you can see our river (Murodzi) is almost drying up. I have to buy more pipes so that I am able to pump water from the small dam, otherwise, my crops* die (Focus group discussant- Major Bown Compound, 27 August 2019).

> *When there is more water in Mazowe, I don't need a pump, I just deep a pipe upstream and the water flows to my garden by natural gradient but as you can see this year we didn't receive enough rains so I am buying expensive fuel for my water pump. I am not even sure if I will make any profit* (Male respondent- Virginia Compound, 15 August 2019)

The respondents' situation was worsened by insecure land tenure/landlessness. They could not make long term infrastructural investment such as putting up small irrigation equipment as they were not sure how long they will stay on the farm. However, some respondents indicated that a lean season had advantages as their vegetables would fetch more money on the market. In a season with normal rainfall, a head of cabbage, for example, was sold from between US$ 0.30 to US$1 but during a drought year, the head was reported to range from US$0.75 to US$1.50. It can, therefore, be seen that despite its negative impact, climate-change had a positive impact on some aspects of the former commercial farm workers' livelihoods.

Gold-panning

Some respondents (n=43) engaged in gold panning. Of these 19.04% (n=40) were males while 1.42% (n=3) were females. The panning was done on selected farms, goldfields and rivers in Mazowe District. Climate-change had both positive and negative consequences on former commercial farmworker households who engaged in gold-panning activities. The gold-panners noted that underground water levels disturbed their panning activities especially those who did underground mining. A low rainfall season, therefore, comes as a blessing to them as they need not meet the expense of pumping the water.

On a different note, former farmer workers cum gold-panners who did alluvial mining along rivers and river banks bemoaned a low rainfall season as a disadvantage for their trade. A lean season was also reported to be an advantage by women who reported fetching and selling water to gold-panners. It was found that some women (n=37) fetched water for the gold-panners which was used in the extraction of the precious stone and the price of water depending on the distance to the water source. This business was popular among respondents at Hemiston Compound and most of the women (n=30) reported that they were happy with the income they were realising from the water-vending. A high rainfall season was also a risky factor for artisanal miners as the wet surface would increase the risk of accidents for underground miners.

Trading in non-agricultural commodities

A number of respondents (44.28%) were involved in various entrepreneurial activities which involved selling various goods among fellow former farmworkers. They exchanged their products with grain mainly maize or soya beans. The products sold were mainly grocery items, second-hand clothes and plastic foot ware. It was noted that climate-change was directly affecting the enterprises of these traders. During years with normal rainfall, the respondents reported high profits and very low profits in years characterised by low or too much rainfall. Sales volumes of mainly food items improved significantly during harvesting periods. Traders who were selling to artisanal minors indicated that any impact whether positive or negative on the mining activities directly affected their sales. They also indicated that rainfall patterns affected the agricultural yields of resettled farmers and this had a bearing on their businesses as these were also employers of some of their clients. Some respondents had this to say:

> *In a drought year, our profitability shrinks and some people even close down their tuckshops* (Female respondent- Protea Compound, 15 August 2019).

> *I sell beer and if we receive good rains I know I will enjoy good profits.* (Female respondent- Mututa Compound, 16 August 2019).

Buying and selling of agricultural products

An insignificant number, (n=25) number of the former farm workers traded in agricultural products mainly maize and soya beans. They bought the products in small quantities from fellow former farmworkers or small scale farmers and sold to mobile merchants. Levels of profits were reported to fluctuate from one year to the other depending on the amount of rainfall received. In a season characterised by normal rainfall, all the 25 respondents reported that they would make satisfactory levels of profit while less or no profit was realised during drought years. The profit levels were also reported to be sensitive to rainfall patterns received from year to year. Too much rainfall was also reported to reduce output per hectare which in turn affected the availability of agricultural products for buying and selling by the former farmworkers. However, it is important to note that in June 2019, the Government of Zimbabwe passed a law (Statutory Instrument 142 of 2019) which prohibited buying and selling on maize except by Grain Marketing Board or its Licensees. This means this livelihood option is no longer available for the former farmworkers.

Brick-moulding and rearing of livestock
Some livelihoods activities especially farm brick moulding and rearing of livestock were found not to be directly affected by changes in climate. Respondents who engaged in these activities reported that changes in rainfall patterns and temperatures did not affect their activities. The former farmworkers reared mainly small animals like goats, free-range pigs, free-range chickens, rabbits, turkeys and pigeons. These required very small amounts of water, which the former farm workers would easily provide.

Farming on rented/ state land
Though the former commercial farm workers were not allocated land during the FTLRP, 27.13% of the respondents grew mainly maize on very small pieces of land, which they rented from the resettled farmers or that allocated by their employers or idle state which was not meant for cultivation. The state land was mainly meant for livestock grazing, wetlands or river banks which were reserved for environmental conservation purposes. Only 5 respondents reported that they had rented land during the data collection period and the mean land size of the rented land was 0.73 hectares. The mean land size for the 57 respondents who reported small scale farming was 850 square metres. These 57 respondents reported being victims to the vagaries of climate-change especially droughts and excessive rainfall. Low rainfall resulted in low output as the crops were stressed by water shortage and excessive rainfall affected output for those mainly cultivating wetlands and river banks. Estimated mean maize yield for the 57 households during a normal season was pegged at 300kgs per household compared to 140kg during a low rainfall season. Too much rainfall was reported to cause a lot of leaching and stranded growth on the crops which also resulted in low yield.

DISCUSSION OF RESULTS
The study results show that climate-change has an adverse impact on most livelihood activities of former commercial farmworkers. Livelihoods activities such as casual employment on farms, gold panning, gardening, buying and selling of both agricultural and non-agricultural commodities were found to be negatively affected by changes in climate, especially low rainfall. Almost all the economic activities that the former farm workers engaged in were directly and indirectly influenced by the effects of climate-change. The former farmworker households were suffering from multiple tragedies of landlessness, unemployment, poverty and vulnerability to the vagaries of climate-change. As noted by Scoones *et al* (2019) most former farmworkers in Zimbabwe have unsustainable livelihood strategies which are not resilient to climate-change. The situation is worsened by landlessness in that they cannot make long term investments due to insecurity of land tenure. For example, in the case of gardening, farmers could invest in small scale irrigation schemes but since they are not sure how long they would use the land it is difficult to make such investment. Climate-change was also found to have indirect impact on former farmworkers who relied on buying and selling goods through barter trade with grain and those who were employed by the resettled farmers. Low or excessive rainfall, which results in low agricultural output meant low profits for former farmworkers in business and fewer employment opportunities for those who were hired on a casual basis.

The findings of the study corroborate a study by Mabvurira and Mpambela (2019) who note that rural livelihoods were heavily affected by climate-change. The landless former farmworkers relied on buying food and whenever there is a poor yield due to climate-change they are bound to suffer more than other rural people who own land. Most former farmworkers stay in delicate houses made of pole and grass. Heavy rains have the potential to destroy their houses and leave them homeless. They build cheap houses due to the insecurity of their land tenure. In most circumstances, they live to the mercy of resettled farmers or influential politicians as noted by Mabvurira *et al* (2012).

Evidence from the study shows that climate-change has caused feelings of stress, anxiety, fear and hopelessness among most former farmworker households. These findings are supported by Ernesto (2017) who found out that lack of resilience and diversity in the face of climate-change may exacerbate poverty and vulnerability among poor communities. The development of mental stress and hopelessness among landless former farmworkers can be attributable to lack of resilient and alternative survival skills. This finding can further be understood from the resilience perspective, which explains that people need to be equipped with diverse skills, which would enable them to withstand the vagaries of change emerging from unanticipated changes.

The former farmworker households were languishing in poor health due to the effects of climate-change. Cases of malnutrition, headaches and heat rush were reported. This confirms results by Brown *et al* (2012) who note that climate-change was slowly becoming a health menace of the century. Prior to the Constitution of Zimbabwe (Amendment number 20 Act of 2013), most former commercial farm workers were not citizens as earlier constitutions did not provide for citizenship by birth. Now that most of them are Zimbabwean citizens, it is imperative for the government to seriously engage this community in its activities.

CONCLUSION AND RECOMMENDATIONS

Climate-change has a serious negative impact on the lives and livelihoods of farm commercial farm workers in Mazowe District. Though they are landless, rainfall patterns directly affect their food security and health. Most of their livelihood strategies such as trading, gardening, gold-panning etc suffer from the impact of climate-change. The study, therefore, recommends that: climate-change resilient strategies in Zimbabwe should also focus on non-agricultural activities to cushion landless rural citizens. These could include giving loans to former farmworkers, offering basic training in business management, encouraging and supporting rotating savings and credit clubs among the farmers. Efforts should be made by the Government of Zimbabwe to allocate former commercial farm workers land so that sustainable climate-change adaptation efforts become easy to implement.

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CHAPTER **07**

CLIMATE CHANGE MITIGATION IN MEDIA DISCOURSES AND PUBLIC ATTITUDES: A CORPUS- AIDED ANALYSIS OF SELECTED MEDIA MESSAGES AND RESPONSES FROM URBANISING PARTICIPANTS IN MVUMA.

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Source: https://emtv.com.pg/communal-farmers-cultivate-maize-crops-in-mvuma-district-masvingo

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ABSTRACT
Provision of information on climate change mitigation can be considered and recommended as one of the ways to empower citizens to undertake positive climate related behaviour. Although this might be true, this study contends that climate change awareness and information are essential, but this alone does not directly result in positive climate-related behaviour change particularly among ordinary citizens. Information packaging and language choices become integral particularly on the nexus between media framing and attitude formation. This study therefore examines the impact of the language cues used by the media in the construction of public belief and attitudes in relation to agency and urgency in climate change mitigation. It interrogates the way in which exposure to information on climate change affects attitudes towards mitigation in a re-urbanising context of Mvuma. In addition, the study also presents some suggested alternatives in the communication processes that are hoped to promote both polycentric and urgent action on climate change particularly in a situation associated with the dilemma of balancing eco-consciousness with the concurrent pull and purchase of urbanisation. From the findings, it emerges that the way in which the Zimbabwean media framed climate change mitigation issues between 2016 and 2019 does not elicit the kind of responses needed for a positive climate related behaviour at both individual and community levels. Based on such findings, the chapter recommends the need for the media to frame climate change issues in a way that connects individuals and communities to the issue and emphasize the strategies of mitigation at individual and community levels.

Key terms: Mitigation, media, language, agency, urgency

INTRODUCTION

For a community and individuals to become earnestly engaged in positive climate change behaviour such as mitigation, adaptation or resilience, some social orientations and media frames are more conducive than others (Boykoff, 2011). Media frames give meaning to and indicate how citizens can interpret events and objects within climate change discourse. Such media communication can range from adjectives describing the object itself to the context of the object. For example, climate change itself can be framed as 'real' or 'illusionary' or it can be discussed in a host of different contexts such as economic effects, political process, policy specifics or allocation of responsibility (Broadbent, *et al*., 2016). Although the norm of media reporting is detached objectivity, reporters cannot but frame both the subject and an object whether purposely or not. This ultimately conveys a meaning about both the subject and the object to the readers. In this way, media frames can influence beliefs, preferences, and risk perceptions, and through these, actions (Nisbert, 2009). In the context of climate change mitigation, some frames can construct mitigation as an action that need to be done by different actors, while other can obscure and reject that need and urgency (Carvalho, 2007). This also means media representations construct particular subject positions for individuals and cultivate dispositions to action or inaction.

Mediated discourses play significant roles in social life as they are both conditions of intelligibility of climate change issues and conditions of possibility of action upon it (Fairclough, 1995). As indicated in research, the media have a significant influence over the perceptions of the 'distant' and unobtrusive issue of climate change (Cabecinhas, *et al.,* 2008). Moreover, the social credibility and authority of different actors, their claims and arguments, are also largely defined by discursive exchanges, which take place in the media (Boykoff, 2011).

The public on the other hand as consumers of media information have their own unique conceptualisation of issues, often called 'frames of thought' which are influenced by frames in communication or considerations that are advanced by speech acts or written accounts (Boykoff, 2011). The influence of the media frames on such frames of thought can be seen as the framing effect. To achieve this framing effect in relation to climate action, the public need to be empowered through the provision of adequate information, sufficient awareness, understanding and appreciation of climate change and other issues of concern (Moser & Dilling, 2011). This is affirmed by Lorenzoni (2007) in saying that, awareness and provision of education is

one way of creating certain attitudes and perceptions towards the uptake of climate relevant behaviour. Although it might be true that climate change awareness is essential, it does not directly result in behaviour change particularly from the general public (Moser & Dilling, 2011). Such sentiments can be confirmed by the actions in the Zimbabwean context in which there are numerous efforts by various stakeholders such as the government, the media and the Non- Governmental Organisations to educate communities about climate change issues. Communities are said to be still reluctant to adopt certain mitigation options suggested particularly in and around their homes as well as their immediate communities (Zimbabwe Human Development Report, 2017). As a result, signs of deforestation, land degradation, pollution and climate- unrelated consumer behaviour such as small car purchase and private transport use, housing designs, energy consuming heating, lighting and cooling systems are still visible (ZHDR, 2017).
Notable researches meant at addressing the lack of behaviour change in the presence of climate change information such as the findings by Shome & Marx (2009) conclude that, climate related information can be fully absorbed and elicit an emotional response by the way of climate related behaviour if messages are packaged in the appropriate language. In this view, communication choices particularly the language features construed as the 'taken for granted' such as modal and tense markers, transitivity options among others offer alternative possibilities for thought and this can potentially influence the uptake of climate related action (Pettenger, 2007). However, in Zimbabwe, the way different stakeholders communicate climate change is well recognised but the nature of language options adopted by such stakeholders is an insufficiently recognised area.

Driven with the aim of illuminating research on the intersection of media communication and formation of public beliefs and attitudes, this chapter explores how perceived agency and urgency for action framed by the media may affect views and responses of people in regards to mitigation. It interrogates the way in which exposure to information on climate change affects attitudes towards mitigation. The research uses a combination of document analysis and focus group discussions to test the effects of differently constructed media messages on perception of climate change and attitudes towards mitigation in an urbanising context. This was done using participants from Mvuma, an expanding highway and former mining town in the Midlands province of Zimbabwe. Consistent with the hypothesis that media framing can influence people's attitudes and responses to climate change mitigation, the study is aimed at bridging the value- action gap between information dissemination and the formation of public attitudes in climate change mitigation at individual and community levels focusing on two independent variables; (i) the type of responses in relation to agency in climate change mitigation, and (ii) the urgency and obligation to act.

BACKGROUND

Zimbabwe acknowledges that climate change is a direct threat to socio-economic development with the potential to reverse the hard-earned developmental gains achieved over the past decades (Brazier, 2017). This is evidenced by Zimbabwe's commitment to international agreements on climate change mitigation, with the ratification of the Paris Agreement and the subsequent submission of National Determined Contributions (NDCs) being a milestone and recent achievement of high impact. However, the representation of such climate change mitigation efforts by the Zimbabwean dominant media is still lethargic and spasmic (Mare, 2011). This is because the reportage of climate change mitigation efforts that are being and ought to be made in communities seems not reflect and construct the urgency of the issue at hand. The quantity of climate change mitigation coverage in Zimbabwean media is disproportionate to the level of the threat posed by climate change (Mare, 2011). Climate change coverage in Zimbabwe revolves mainly around speeches by government officials, workshops and international conferences such as Conference of Parties (COPs). This shows that climate news in Zimbabwe media are event based as opposed to field work generated (Chagutah, 2010). In addition, the coverage is still negative as it is event based, official centred, centred on crises or non- compliance to regulations and when images are used they often tend to be disaster centred meant to shock readers (Mare, 2011). As a result, climate change news coverage in Zimbabwe becomes event- centred hard news, falling within related frames of risk, uncertainty, fear, outrage and crisis (Nisbert, 2009). It has been observed that, the framing of the stories related to climate change, mainly retain the readers' attention and inform them of what is going on rather than mobilising the people to adopt climate- relevant behaviours in their communities (Mare, 2011). This stimulated this study as it explored the way in which media messages can influence the perceptions of people on agency and urgency in climate change mitigation.

STUDY AREA AND METHODOLOGY

Study area

The study was carried out in Mvuma, a former mining and highway town located at the intersection of Harare- Masvingo and Gweru highways. The small town has an estimated population of about 7000 people, and it has been undergoing urban decay since the closure of Athens mine in 1996. People were migrating from Mvuma to other cities such as Masvingo, Gweru and Harare, leaving the town descending into a ghost town status for years since 1996. However, due to the flourishing of fast food business in 2010 through the setting up of Chicken Slice complex, the small Midlands town has been experiencing urban renewal from that period. This has been accompanied by the setting up of other business ventures such as truck shops, fuel service stations, supermarkets, banks and an increase in the demand of both residential and commercial stands. All these development have transformed the small highway town from a sleepy business centres to become one of the promising and growing business centres in Zimbabwe. As a result, in 2018 the government of Zimbabwe approved the northwards expansion programme for Mvuma by allocating it more land surrounding the town (*Chronicle*, 2018). The development has set a scene for urbanisation in the small town of Mvuma as people were allocated more stands since 2018.

Such developments make Mvuma a good study context because urbanisation is associated with forest clearance, land degradation, affluence and lifestyle choices, and increased demand in energy for lighting, heating and cooling as well as industrial processes which lead to greenhouse gas emissions. Taking cognisant of this, this research explores the nature of information being disseminated by the media and makes an attempt to assess the nature of dispositions likely to be formed by people taking the case of Mvuma in which there is high possibility of competing interests emanating from the need of eco-consciousness in urbanisation planning and the concurrent pull and purchase of urbanisation such as affluence and lifestyle choices, forest clearance, motoring choices, housing designs as well as lighting and heating options.

Research methodology

The approach in this study is based on the assumption that in any controversial area there will be competing ways of explaining events and their history. In view of this, a combination of data gathering tools was used to obtain information on the nexus between media framing of climate change and the formation of public attitudes and dispositions in relation to climate change mitigation. The aim of the study was to establish why new messages vary in effects and to identify the possible triggers for potential behaviour change. Guided by this, the researchers developed methods, which involved immersing participants in a new information environment, which the researchers constructed. This was done through a series of focus group discussions conducted in Mvuma town, particularly with those participants who were purposively recruited on normal socio-demographic criteria with an additional criterion being the involvement in the urbanising activities undergoing in Mvuma town. The free form of discussion found in focus groups enables the researchers to establish aspects of the studied topic that could not have been anticipated, but that are raised spontaneously in discussion and thereby proven to be important to participants. Focus groups offered a method for analysing what participants bring to the group and constitute what Jovchelovitch (2001:2) calls "thinking societies in miniature" in which the process of joint sense- making may be studied in action.

In the focus group sessions, the researchers began by measuring the people's attitudes and beliefs on the issue of climate change in general as well as mitigation in particular and then exposed them to new information in form of television and newspaper reports showing the impacts and initiatives meant to reduce the impacts of climate change. Such media articles were obtained from purposively sampled internet picks of online versions of climate change stories in *The Herald, The Chronicle, Sunday Mail* and *ZBC Online* published between 2016 and 2019.[6] Such data were relevant in establishing the 'meaning making' processes made by the media in relation to climate change mitigation particularly in the Zimbabwean context.

Data sources and collection methods

The study adopted a mixed method research design in both data collection and analysis. Three data collection techniques were employed, namely document analysis, focus group discussions and the *Antconc*, a corpus linguistics software. Both quantitative and qualitative techniques were used to analyse data and to present the findings, namely corpus linguistics, thematic analysis and pattern matching. Corpus linguistics provided a quantitative dimension thereby addressing the issues to do with dominant linguistic patterns in both media discourses and the public's responses. Critical Discourse Analysis (CDA) from the perspective of Van Dijk (1993) was applied to pinpoint the specific features of language with implications on the formation of public attitudes thereby providing a qualitative dimension to the study. This dimension is interested in the power of linguistics choices as well as rhetorical devices by certain actors in reaching certain goals. It involves the examination of the strategic use of lexico-grammatical means, which are used in an attempt to influence the mental modes, knowledge, attitudes and eventually ideologies in the audience. The Attitude subcategory of the Appraisal framework was also employed in revealing the attitudinal patterns of selected Mvuma residents in response to the media framings on mitigation and climate change action in general. In collecting the data, the *Antconc*, a corpus linguistics software designed by Antony (2012) was used to retrieve, annotate and build a corpus of approximately containing 125 standardised media texts which generated about 26 737 tokens. The articles which form the corpus were purposively selected from *The Herald, The Chronicle, Sunday Mail* and *ZBC Online* websites from 2015 to 2019. The same software was used to build, retrieve and analyse, the corpus generated from the responses of 30 participants who were randomly selected for interviews.

Data analysis procedures

In the analysis of the data, the major concern was on the frequency and collocation of certain lexical items. Following Baker (2006), a wordlist was generated from the two sets of corpora to obtain the lists of words and tokens displayed in terms of frequency. Frequency lists were helpful in exposing the ideological underpinnings of the selected media discourses as well as the attitudes, feelings and perceptions of the people in regards to climate change mitigation at and in around homes as well as their immediate community. Critical Discourse Analysis was exploited as a way of explaining the relationship between the text, discursive process and social processes. In addition, the Appraisal framework by (Martin & White, 2005) was also applied to identify positive and negative issues from the language features dominant in the corpus generated from the responses of people. Taking cognisant of this, samples of participants' responses were coded either (+) positive or (-) negative and also further distinguished as either inscribed (explicit) or being evoked (implicit). The expectation was to have a broader spectrum of lexical items to be evident in their responses in relation to climate change mitigation in the expanding context of Mvuma town. In answering the question regarding residents' perceptions and attitudes, attention was paid to what the data said about climate change action, when to act and what to do. The major concern was on content words such as nouns, adjective, adverbs and tense markers.

6 The choice of these media types was motivated by the circulation and reach of these newspapers in Mvuma.

RESULTS AND DISCUSSION

Impact of media framing on the construction of agency in climate change mitigation

The results from the frequency analysis of media corpus show that climate change is mainly reported in the selected media articles using the images and narratives of extreme weather events and disasters. Reference to climate change in the media corpus collocates significantly with lexical items such as *risk, danger, havoc*, *disaster, ravaging*, *tackling, fight, combating, and action.* Out of the 26 737 word media corpus compiled from the selected articles from the above mentioned media outlets, the frequencies of the collocates[7] of the phrase climate change across all the media articles are as follows; *disasters* (88), *weather events* (71), *risk* (62), *tackling* (44), *figh*t (41), *adap*t (40) and *mitigat*e (32). Such distribution shows that, climate change is discursively constructed in terms of negative climate change impacts by the media. It is mainly constructed in terms of weather disasters as shown by the frequency of the words such as disasters and other collocates which include adjectives such as *risky, escalating weather events* and r*avaging*. The use of such adjectives and adverbs implies the negative consequences associated with climate change. Such lexical items show that the phenomenon of climate change is a threat (*risk)*, it is continuing (*escalating)* and destructive (*ravaging)* as well. However, the frequency of other lexical items such as *tackling, combating, fight, adaptation and mitigation, which* relate to climate change action, is low as compared to the impacts of climate change. In view of these results, it is apparent that the media emphasize the impacts of climate change, with minimal emphasis on climate action. The findings confirms the observations made by Nisbert (2009) who found that the media report on climate change according to frames which mainly emphasize extreme weather events, risk, uncertainty, fear, outrage and crisis. This is evidenced by the high frequency of such terms which relate to the impacts of climate change in the media corpus in this study.

Peoples' beliefs and perception of climate change

In eliciting the kind of beliefs and attitudes held by people before the exposure to new information on climate change from the media, the moderators' first question was; *what do you think when you hear or see the word climate change*? The aim of the question was to gain insights into the participants' spontaneous association with climate change, what was in their minds in relation to climate change. Participants in all the five groups provided examples of climate change impacts such droughts, heatwaves, floods with Cyclone Idai being the most cited example. From such responses, it is apparent that climate change is conceived by the participants as extreme weather events. Asked about the sources of these examples, the participants responded that they observe it from the physical environment but they are told that it is climate change by the media. From the participants' accounts it seems that the communication by the media is consistent with the beliefs they have in regards to climate change.

After establishing the views and levels of engagement with climate change, the researchers introduced new information in form of the constructed television and newspaper reports on climate change. The aim was to elicit the kind of responses given in relation to the way climate change if framed by the media. The moderators' question was; *what do you think should be done given the way in which climate change is presented in the media reports?* The responses show that they acknowledge the existence of the phenomenon but the way the way the media communicate the issue does not show where their contribution lies. The participants acknowledges the severe life threatening impacts but responses to climate change were framed as a matter of uncertainty as shown in the extract below; (The responses were transcribed and translated from responses made using Shona language).

Extract 1

1 Moderator: Given the information you have obtained from the media, what do you

7 Collocates are words which exist together with the root node. This can be before or after the core word.

think should be done to reduce the impacts of climate change particularly in in your area which is undergoing some developments related to town growth?

2 Participant 1: As for me, I think what shown by the media and what we are seeing is a clear sign that the end is near and I don't think we can do something to it. Our focus then we must see how we can protect ourselves from destruction.

3 Participant 2: Yes, I agree with [XXX], even the Bible show things like this, like in the case of Noah. It will come and pass, the future is better, I believe so

4 Participant 3: Climate change is there as they show (media), but how can my individual contribution matter in that. More so, how can I act more on climate change when I need to sustain my livelihood?

5 Participant 4: As for me, I don't know what to do, as you can see they tell us what climate change is but not what we can do as individuals so we end up thinking something must be done by someone who is not us.

Extract 1 illustrates how focus group participants jointly constructed their representations of climate change mitigation. In turn 2, the participant responds to the moderator's question about what they think should be done by mentioning that they do not know what they should do since the issue is a naturally occurring phenomenon. In turn 5, the participant 4 also concurred with participant 2 in noting that the media just inform them about climate change but not exactly what they can do at individual level as in most cases action on climate change is framed in relation to government action.

As evidenced from the responses above, people try to absorb new information through existing frames of reference but such frames are also influenced by the frames in communication (Moser & Dilling, 2004). From the responses, it may be deduced that due to the frequent association of climate change and weather disasters in the media, the "weather" frame might also have been triggered among the audience. However, the coattails of the common conflation of weather and climate change becomes synonymous with and erroneously restricted to a change in weather. Weather and disasters are generally understood as natural phenomena not controlled by humans but are regarded as 'acts of God'. This explains why some participants find no reason to intervene as shown in extract 1. Consequently, this frame suggests that climate change can neither be caused nor solved by humans. Based on these observations and discussion, it is apparent that it is significant that in climate change communication, language cues must be chosen carefully. Failure to do so might leave the audience with inappropriate mental models to make sense of new information and understanding of the causal mechanisms, and the identification of relevant solutions. The effect of this is that, when people do not understand their contribution to the issues, they also lack agency to it as shown by the responses provided.

The conclusions that can be derived from the findings above resonates with the views of Luntz (2002) and Lee, *et al* (2015) who noted that, descriptions of the escalating climate phenomena must relate the issue to the immediate environment of the people and explicate the people's contribution in either causes or solutions. The routine usage of the phrase 'climate change' itself seems to be decontextualized from ordinary people's environment as what the term means has differing technical contexts as well as the non- technical contexts such as simply *'climate change'* as equivalent to '*climate changes*' or *'changes in climate'* where the operative word '*change*' slips back and forth between a noun and a verb (Lee, *et al.,* 2015). The whole phrase therefore refers to all changes in climate including natural changes of the past in addition to the current human induced change. Although this might be true, Lee *et al (*2015) contends that, the term 'change' is a neutral term that does not convey that humanity is the culprit behind what is happening. It can be correct that climate is always changing, but the shifts in weather such as sea-level rise, ocean acidification and melting glaciers are not climatic (Lee, *et al*., 2015). The whole phrase therefore sounds rather passive and gentle especially in describing the escalating climate catastrophe and what it is doing for humanity. More so, the term can be regarded as less frightening as it suggests a more controllable and less emotional challenge (Luntz, 2002). As a result, if the term means climate is always changing it is likely that people cannot find the deal in intervening in naturally occurring events.

In regards to the above, comfort in such business-as- usual term to describe the climate phenomena when the issue itself is escalating is likely to yield the same results as those being obtained over the years in climate change mitigation calls. This is because the choice of words can invoke, connote or direct attention as it is psychologically proven by Shome and Marx (2009) that, harnessing the power of communication in descriptions of climate change can focus the minds of the general populace towards environmental issues. The paper therefore contends that engaging the public implies the media doing a strategic work on motivating or persuading people toward a certain (externally defined objective which in this case is climate change mitigation). Communication is typically concerned as a means or instrument for influencing behaviour.

In addition to the above observations, the results also demonstrate how agency is created or inhibited through the adoption of some communication strategies in the media. It has been established that the media also report climate change using alarmist language, hard hitting language, fear appeals and projections of negative climate impacts. In the sample from the media corpus, adjectives such as '*ravaging*', '*devastating*' and others such as *'brunt', 'deadly', 'grappling'* were ranked high in terms of frequency. This is done at the expense of the positive climate related behaviour exhibited through the use of lexical items such as *tackling, combating, fight, adaptation and mitigation* which recorded low frequency in the corpus.

The findings from the respondents on the other hand show that people wanted to learn about the positives about climate change, particularly how they can contribute in the reduction of the negative consequences of climate change. In responding to the moderator's question on what they think the media must do to encourage climate action, below are the responses (responses were translated from Shona);

Extract 2

1 Moderator: Given that you receive much of the information on climate change from the media, and from what you see, read and hear what do think, the media must be doing to encourage climate action?

2 Respondent 1: I think, it is rather unnecessary to tell us what climate change is doing to us only because, we see this by ourselves, the media must be a platform to tell us the options.

3 Respondent 2: I also think that, the damage has been done and we can continue with the damage if we are not educated on what we need to do as we plan for the new town remember the first thing is we need to survive and develop.

4 Respondent 3: They (media) are saying people have contributed to the situation we are having, and I think to continue with the blame game is something that will make us stuck in nothing, better educate us on the way forward.

5 Respondent 4 : The media is doing great, but some of the pictures and images are frightening to the extent that we lose hope.

6 Respondent 5: The crisis is there, it is fierce indeed as shown in the visual both from television and newspapers, look at the pictures from Cyclone Idai, but I think they need give us examples of how other people are doing it so that we can do same in our context. We cannot just wake up and do the right thing, No.

From the extract, it is apparent that people are committed to act, but the engagement strategies used by the media seem not to motivate them to adopt proper mitigation activities. In turn 2, Respondent 1 shows willingness to act, if the mitigation actions are provided and suggested for them. Respondent 1's sentiments concur with Respondent 3's views in turn 4 in which, she indicates that they are not aware of what they can do, they remain to be guided by the media. In Turn 3, Respondent 2 also indicate the need for solutions to be presented to them so that they know how to balance economic activities and environmental objectives.

From the findings above, it can noted that although multiple agency requires multiple prerequisites such as adoption of good governance, incentives and proper education, the content of communication is also crucial. The findings from this study reveal that there are shortcomings in fear based communication as shown in the responses provided by the participants. Such alarmist messages and visualisations proves to be useful in increasing public awareness of the impacts as also testified from the responses by focus groups participants. Narratives and images from the media are likely to engender feelings of hopelessness and apathy in the audience as echoed by Respondent 4 in turn 5 of extract 2. Such findings are also consistent with Moser & Dilling (2004) who establish that what grabs attention is not what empowers action and that fear appeals without effective ways to counter them frequently result in denial, numbing and apathy.

Contrary to the assumption that fear appeal is one way to raise awareness, it has been established that it is important to communicate awareness raising messages that still hold the potential to empower people to take action. Research evidence suggest that climate action can be achieved through communicating local impacts and responses to climate change, and highlighting concrete action strategies (Nicholson-Cole, 2005). Climate change related messages as shown by the participants' narratives in extract 2 should focus on solutions rather than problems.

In addition, the participants also jointly reveal that there is need for the media to provide examples from other communities particularly on the actions they are undertaking for them to imitate and implement in their context. This is shown in turn 6 of the Extract 2 in which the participant intimate the need for examples so that they can do the right thing. Such narrative is also consistent with Howell's (2011) sentiments that, positive stories of how ordinary people (not environmentalists or politicians) take action on climate change seem to be a promising road for climate change communication since such stories take advantage of the power of constructive social norms. This resonates with Cooney (2010), who echoes that such locally based projects and examples from other communities can be useful in fostering public engagement and promoting a sense of agency and control for lay people.

More so, it must be noted that climate change is often perceived by the public as a remote risk both spatially and temporally (Spence, *et al.,* 2012). There is need to make it visible and to do so, the role of visualisation through linguistic means such as metaphors or images must also be emphasised. Consistent with this are what Hamblyn (2009) calls 'canaries' in climate change rhetoric such as individualised instances of warning signs or wake up calls that alert people to the presence of wider perils. In the context of climate change concern in Zimbabwean media, such canaries have been seen in the repeated images of cracked earth surface and the blazing planet as shown in Figure 1 above. This render climate change visible, but this can have an effect of relegating climate change impacts to a remote place where habitats and environment are affected not humans. Research evidence on the contrary has suggested that climate change images and language should be non- threatening and link people's everyday concerns and emotions (O'Neil & Nicholson- Cole, 2009). Focusing on concrete, locally-relevant impacts and responses to climate change could be seen as a way of encouraging experiential learning which start from concrete concepts and experience as a basis for reflection, thinking and action. As established by O'Neil & Nicholson (2009:3), images and language forms that stimulate the greatest feeling of personal efficacy are those clearly showing what people can personally do. From such discussion it can deduced that agency in climate change mitigation particularly among lay people such as the urbanising participants in the context of Mvuma can be achieved through harnessing images and language forms that not only provide a diagnosis of the problem of climate change but which also offer some solutions (feasible treatment).

Urgency and obligation to act

On the subject of changing behaviours and acting with urgency, the public opinion as exhibited by the participants does not register an urgent concern of climate action. Climate change mitigation in the light of the 2015 Paris Agreement must reflect the urgency captured in the introduction of the agreement's document. The aspect of urgency is captured as follows; '*Parties recognise the need for effective and progressive response to the urgent threat of climate change.'* (unfccc.int). In this regard, there are expectations of forceful language use on the necessity to undertake action rapidly in order to tackle climate change.

The participants in the focus groups acknowledged the fact that climate change is an urgent threat and they also showed a strong awareness of acting towards reducing the negative impacts of climate change. However, in such acknowledgement and concern, the majority of the respondents seems to be otherwise preoccupied. Whilst costs and convenience were cited by the respondents as reasons for not making changes urgently, the sense of powerlessness, that they cannot make a difference and that, at policy level those in authority could not be trusted in their decisions for a greater good also played a role in this disengagement. They consider climate change as a less pressing issue than town development, construction of human settlement, creation of employment, with ethical issues such as re-afforestation, adoption of climate friendly technologies characterised as luxury for more prosperous times to come after urbanisation.

After establishing the views and levels of engagement with climate change mitigation, the researchers then introduced new information in the form of the constructed television and newspaper reports on climate action. The selected stories were concerned with initiatives being taken to limit the emission of greenhouse gases in the country. In the selection of such stories, the focus was on how mitigation was constructed particularly in regards to meaning related to obligations often expresses through modal verbs such as *ought, shall, should, must, will* (Le Querler,1996). The distribution of the four studied auxiliaries in the media corpus in the current study was as follows; *will* (284), shall (96), *should* (76*), must* (67). This shows that the auxiliary *must*, with the strongest volitional stance in the media corpus has the least frequency which indicates a clear lack of obligation and necessity and perhaps urgency in the selected media discourses.

In the media corpus there is high frequency of the modal auxiliary *will,* occurring in about 284 instances and distributed as follows in the selected media articles; 172 times in *The Herald* (n= 27) articles, 58 times in *The Chronicle* (n=14) articles, 28 times in *Sunday Mail* (n=10) articles and 26 times in *ZBC Online* (n=9) articles. The modal tense marker *'will'* collocates with verbs such *occur, mitigate, approach, create*, *push, and fight.* All these verbs show that there is intention of taking action as they are all action verbs. However the use of *'will'* shows futurity as shown in some selected examples below;

Extract 3

*Much of the mitigation **will** occur in the energy sector...* (**The Herald, 1 October, 2018).**

Extract 4

"*As the church, **we will** approach different offices and different groups that can assist us as a nation to have unconditional support or compensation for the bad effects that are being caused by climate change. "**We will** create communication strategies between the people and the stake-holders as well as liaise with Government to normalize its political relations with other nations so that people will also benefit from this global climate change compensation." **(Sunday Mail, 17 January, 2016)***

Extract 5

*"Government **will** integrate the necessary mitigatory measures into national policies, strategies and planning, to strengthen resilience and adaptive capacity to climate related hazards and natural disasters."* (**Sunday Mail, 16 November, 2018).**

Presented with such attention to the subject of climate change mitigation in the media, the participants demonstrated a confirmation of the feeling that mitigation was a less pressing issue which was shown before exposure to new information. From the responses by the respondents, it is unsurprisingly that there is lack of emergency tone, their narratives also expresses non- specific predictions, through the use of *will* as well as other time adverbial such as the *if* constructions as shown below,

Extract 6

1 Moderator: From the information you are receiving from the media reports, when do you think is the right time to act as you aim to have a climate smart town?

2 Respondent 1: As you can see from the stories, there are some things which need to be done before we start acting because development is needed first. How can you go for smart ways when you do not have shelter, employment and income, we will do so in the right time or **if** they help us with some of those things you consider to be best for a climate smart town.

3 Respondent 2: I agree with her in that action is needed but not now, our focus in the meantime is on improving livelihoods in the best way we can until the authorities lead us in the correct way.

4 Respondent 3: The media reports are correct, how can we rush to act now when the President is saying we need to reduce emissions by 2030. We will act because the effects affect us. This is when we get proper information on how to do it.

5 Respondent 4 What has been said is correct there is need to do something, but look, there are some things that makes sense right now like employment

> creation. This is why the media reports are saying mitigation measures will be and this is because they are aware of those first things.

The responses from the participants show an overwhelming feel that mitigation is a less pressing issues than other economic activities. There is consistency with media framing of the projections of climate action which are mainly expressed in form of some prediction on the future which is non- specific (timeless) in this case. The main reason for such resonance, can be attributed to the fact that the framing are tapped into existing views and attitudes that mitigation is an activity of the future. The frequent use of *will* in the media articles has the potential of triggering the frame of climate change as an intangible thing which also reduces the propensity to act. As noted by Wodak (2001), the use of the modal marker '*will*' falls greatly under deliberative oratory (*genus deliberativum)* which is connected with the future and thematically related to expediency of harmfulness (Wodak, 2001). **'***Will'* is used as an epistemic marker and this marker is quite vague in terms of its meanings as it can convey volition/ intention or a simple future time reference. *Will* can be used as a volitional marker of high value to express determination in climate change mitigation. This can be determination that pursuing mitigation is the right thing and will certainly be actualised. However, the use of *will* can be vague and ambiguous as it can have two readings. The first reading is of a promise to take action in terms of volitional modality. The second reading is of certainty in doing so in terms of epistemic modality. As there is no time limit in in the use of *will* in all the above cases, the epistemic meaning becomes hypothetical and therefore the volitional stance becomes weaker (Simon- Vandenbergen, *et al*., 1997. As a result, the usage of the auxiliary in the media discourses under study shows lack of urgency to act.

The findings therefore confirm the evolutionary reason perspective which says, 'humans have a limited attention span to devote to non- immediate problem' (King, 2019). In addition, due to complexity of climate change, it is unsurprisingly that climate change mitigation does not rank on most participants' lists of concerns. While most of the group participants have heard of climate change from different sources and believe it is an important issue, a smaller percentage is actually personally concerned about it. Climate change does not even fall within the top five priority issues in an urbanising context such as Mvuma. Just because climate change is an environmental issue, thus automatically assuming a lower priority relative to more immediate socio-economic goals (King, 2019).

More so, the findings also confirms the classic time management literature which says that humans spend most of the time on issues or demands perceived as urgent. The media tend to portray the climate change issue as one which is largely uncertain and fail to create a solid understanding of the potential solutions to climate change. Without such an understanding, individuals are left with overwhelmingly frightening images of potentially disastrous impacts with no clear sense of how to avert this and therefore the way to direct urgency towards remedial action.

CONCLUSION

From the analyses made above, it can be deduced that although climate change impacts are escalating, the Zimbabwean media is still far from treating the issue in a business-unusual manner. As a result the public remain disconnected from it and they are not motivated to act toward reducing emissions as they are failing to understand their contribution to what they regard as a naturally occuring phenomenon. The study also established that agency in climate change mitigation particularly among lay people (who are not environmentalists) such as the urbanising participants in the context of Mvuma can be achieved through harnessing images and language forms that not only provide a diagnosis of the problem of climate change but which also offer some solutions (feasible treatment). More so, from the observations made and responses given by the participants, climate change mitigation does not rank high on participants' list of concerns in an urbanising context. Urbanisation practices have ramifications for mitigation that involve a complex mix of benefits and trade- off that require the participants to balance multiple economic and environmental objectives. In respect of this, there is need for consciousness in both the communication context and content to adopt persuasive strategies in language use that necessitate the need to undertake actions rapidly in order to tackle climate change.

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CHAPTER 08

IMPACT OF CLIMATE-CHANGE ON FALCIPARUM MALARIA PREVALENCE IN MASVINGO URBAN, ZIMBABWE

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ABSTRACT

The effect of climate-change on Malaria dynamics remains veiled in obscurity. In this study, we use a post-positivist research paradigm and a mixed methods research design to examine the sensitivity of Malaria patterns to changes in rainfall and temperature patterns in Masvingo urban, Zimbabwe. 40 years (1974-2014)and 30 years (1974-2004) historical climate data was used to compute climate trends. 16 year (2000-2016) epidemiological data were used to compute prevalence trends. The climate and epidemiological data was used to compute correlations and determine modifications of Malaria patterns. Clustered random and chain referral sampling approaches were used to select study sites and respondents. Primary data was gathered through a questionnaire, interviews and focus group discussions. The Mann Kendal trend tests were performed using XLstats 2018. Results show that there is a significant change in climatic variables over a forty-year period. Thirty-year period variable data also indicate significant trends. A positive correlation between Malaria cases and temperature-related variables was observed. A positive correlation was also observed between Malaria and precipitation-related variables. These observations were confirmed by views of the respondents, reflecting that climate-change has a bearing on the proliferation of Malaria in the City of Masvingo. It is the conclusion of this study that climate-change is contributing towards influencing the spatial and temporal dynamics of Malaria in Masvingo urban. The study recommends further research into adaptation mechanisms that can build the resilience of Masvingo Urban communities to the negative transmutations associated with weather and climatic caprices.

Key words: Climate-change, Malaria, vector-borne diseases

INTRODUCTION

From the tropics to the polar regions, climate and weather have a powerful direct and indirect impact on human life (UNFCCC, 2007). Climate-change-related events have endangered health as well as destroy property and livelihoods. A plethora of parasitic, viral, and bacterial diseases are sensitive to climate whether through their geographic distribution, seasonality, inter-annual variability, or temporal and spatial trends (Thompson *et al*., 2018). Changes in climatic variables, especially temperature, affect the life history of biting insects and consequently vector-borne diseases such as Malaria (Brand and Keeling, 2017). In general, most biological processes occur at a faster rate at higher temperatures, although not all processes change in the same manner. Changes in the global climate bring a range of risks to health, from deaths in extreme high temperatures to changing patterns of infectious diseases.

The sensitivity of malaria and other vector-borne diseases to climate continues to raise questions over the implications of climate-change on future disease dynamics (Gwasira *et al*., 2016). Malaria poses a significant threat to global populations, affecting millions of individuals each year (WHO, 2014). Malaria contributes significantly to the global burden of disease, dislocating health systems and cause a plethora of socio-economic problems (Campbell *et al*., 2015; Lozano *et al*., 2012; WHO, 2008). Underdeveloped countries and low socio-economic status societies are more vulnerable with outbreaks in southern Africa being highly prevalent at endemic levels. The current proliferation of malaria and concerns of global climate-change have provoked questions regarding their potential relationship (Servadio et al 2018; Medlock et al, 2015; WHO, 2014). The current trends of increasing temperature and highly variable weather threaten to undermine recent global progress against vector-borne diseases, malaria included (Campbell *et al*., 2015). The insect vectors that transmit malaria and the pathogens and parasites that cause Malaria show sensitivity to temperature and precipitation (Servadio *et al*., 2018).

Servadio *et al*., (2018) put forward that mosquito-borne outbreaks occur with the highest frequency compared to other vector-borne diseases. Malaria is amongst common diseases transmitted through mosquito (WHO, 2014; Medlock and Leach, 2015; Parham *et al*., 2015). As a result, infectious diseases transmitted by mosquitoes raise curiosity amongst researchers and medical practitioners. Mosquitoes are known to breed under warm and wet conditions thereby inspiring interest in exploring their sensitivity to temperature and precipitation patterns (Servadio *et al*., 2018). Scholarly work has shown that higher temperatures are related to outbreaks, but the composite dynamics between the environment, vectors, and disease- transmission require further scientific interrogation (Githeko *et al*., 2000; Patz *et al*, 2005; Lafferty, 2009; Tabachnick, 2010). Specifically, ranges in temperature, especially extreme temperature effects, may compromise the dexterity of vectors to transmit disease pathogens (Parham *et al*., 2015). Diurnal temperature ranges have been found to be more important than average temperatures when examining the development and transmission of malaria.

There is a deluge of research work conducted to assess the impact of climate-change on the dynamics of malaria (Craig *et al*.,1999; Ngarakana-Gwasira *et al*., 2013; Parham and Michael, 2010 and Paaijmans *et al*., 2013). However, most studies tend to consider the effect of temperature alone on the dynamics of malaria, neglecting the impact of rainfall (Ngarakana-Gwasira, 2013). Assessing the contribution of temperature and rainfall in malaria transmission is of critical importance in view of climate-change since the changes have the propensity to alter vector development rates, shift vector geographical distribution, and alter transmission dynamics. Generally, several scholars concur with the view that climate-change is expected to significantly influence the spatial distribution, intensity, and temporal dynamics of malaria.

In the early 1990s, there was little awareness of the health risks posed by global climate-change. This reflected a general lack of understanding of how the disruption of biophysical and ecological systems might affect the long-term well-being and health of populations. Previous studies indicate that the burden of disease from climate-change in the future will continue to fall mainly on children in developing countries (Campbell, 2015). People in developing countries may be the most vulnerable to health risks globally, but climate-change poses significant threats to health even in wealthy nations (Campbell, 2015).

In developed countries, malaria is among the most well-studied of the diseases associated with climate-change, owing to its large disease burden, widespread occurrence and high sensitivity to climatic factors (Campbell, 2015). This is not the case with most developing countries. Despite the widespread occurrence of malaria in Zimbabwe, little has been done to ascertain how it may be a result of climatic vagaries being experienced. In Masvingo in particular, the impact of climate-change on malaria remains veiled in obscurity. The paucity of scientific knowledge about climate-change's influence on the proliferation of malaria subjects local health strategies to implementation challenges. In view of this gap in knowledge, this study examines the impact of climate-change on malaria in Masvingo Urban.

DESCRIPTION OF THE STUDY AREA AND METHODOLOGY

Study Area

The study was carried out in Masvingo city, the capital of Masvingo Province located in south-eastern Zimbabwe (Figure 2). The city is close to Great Zimbabwe Monuments, the national heritage site from which the country takes its name. The city comprises eight main suburbs namely Mucheke, Victoria Range, Rujeko, Rhodene, Target Kopje, Zimre Park, Clipsham and Eastvale. The suburbs can be categorised into high, middle and low-density suburbs.

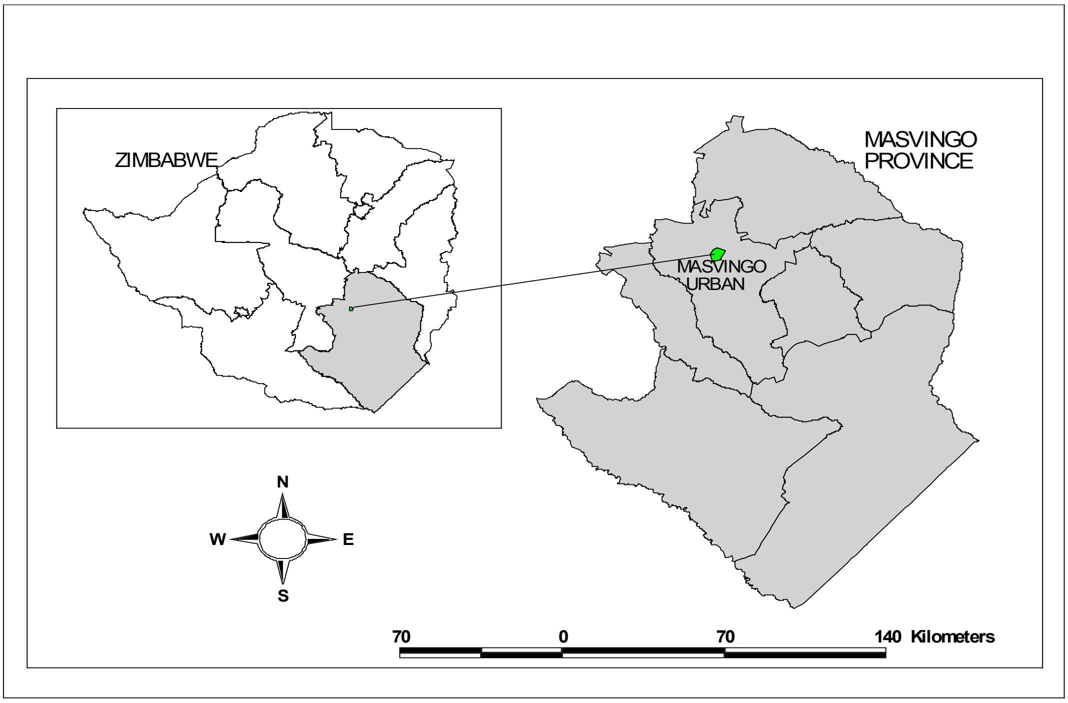

Figure 1: Map of the study area

Mucheke and Rujeko are the most populous high-density suburbs. The middle-density suburbs are Eastvale located close to Zimuto Police Camp, and Target Kopje located on the southern part of town on a small hill close to Flamboyant Hotel. Rhodene, a low-density suburb on the northern part of the city centre, is the most affluent suburb in Masvingo. A new suburban development, Zimre Park, is also taking shape to the northeast of the town along Bulawayo Road. The weather is hot and dry throughout the year, except during the summer when the rains come. Mucheke and Shagashe rivers run close to the centre and both act as de facto boundaries of the central business district.

Research Methodology

Conceptual framework

This study is premised on a concept which places meteorological variables at the core of vector-borne disease transmission. It shows that climatic conditions (as determined by temperature and rainfall characteristics) are the key indirect determinants of the proliferation of vector-borne diseases. The influence of meteorological factors is less direct, and more diverse, both within and between individual diseases (Smith, 2014). The simplest connections are through temperature, affecting the biting, survival and reproductive rates of the vectors, and the survival and development rates of the pathogens that they carry (Figure 2).

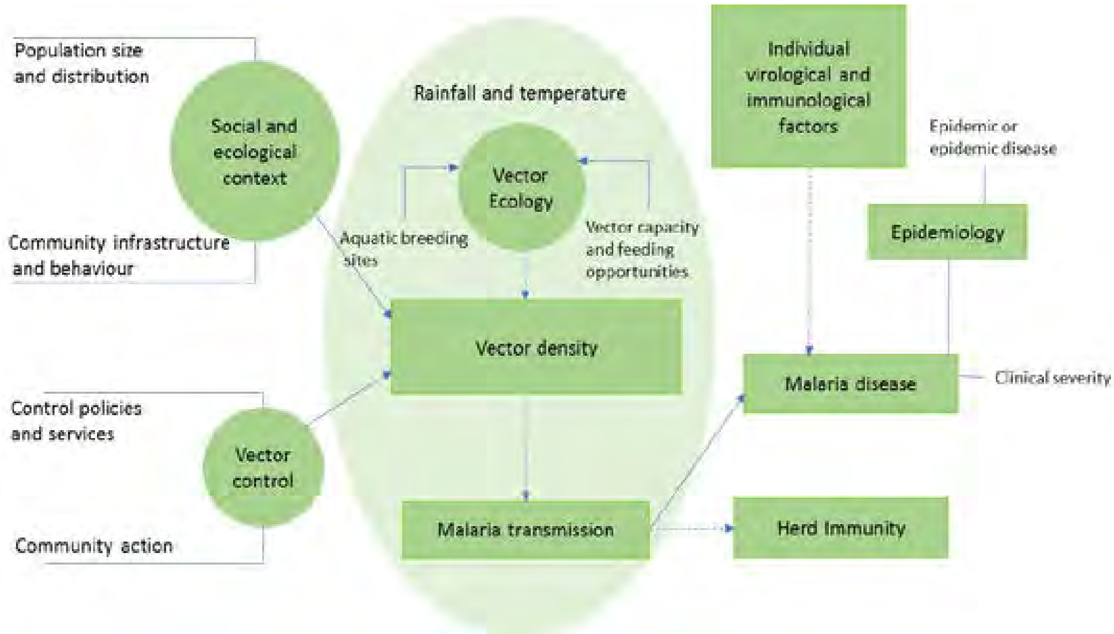

Figure 2 Factors influencing Malaria transmission cycles: Developed by author, modified from Campbell et al 2015

Precipitation also exerts a very strong influence through creating conducive environments for mosquitos which cause malaria. Population characteristics such as size, distribution and behaviour also influence the proliferation of malaria. Human influence can occur indirectly through modification of ecological systems that directly enhance the proliferation of vectors that have aquatic developmental stages. In the context of the conceptual framework shown in Figure 2, this study investigates how meteorological factors (temperature and precipitation) influence the development of vector-borne diseases.

Research Philosophy

The study adopted the post-positivist research philosophy which is known as methodological pluralism concerned with the subjectivity of reality and moves away from the purely objective stance adopted by the logical positivists (Morris *et al*., 2009). The post-positivistic research paradigm assumes there are many ways of knowing besides using the scientific method (Mc Gregory and Murnane, 2010; Ponterotto, 2005). It also assumes that research should not be value-free and unbiased but be value-laden, subjective and inter-subjective, even value-driven within the critical paradigm, giving room for the voice and role of the researcher and participants in the study. The post-positivistic paradigm was thus adopted because it incorporates two paradigms that were deemed important for this study, whereby the positivistic view was considered for the analysis of meteorological data and the interpretivistic view was considered for determining the effects that climate-change on vector and water borne diseases in Masvingo Urban.

Research methodology

The mixed methods methodology was adopted as the strategy of inquiry. The methodology uses both quantitative and qualitative methods (Gray, 2011). The quantitative approach is rooted in the positivist paradigm (Collins, 2010) while the qualitative approach is grounded in the phenomenological philosophy (Corbetta, 2003). Morgan (2008) postulates that the mixed methods design emanates from the pragmatic school of thought and is being widely used by researchers from various disciplines. The approach is also rooted in the argument that knowledge is generated from activities, circumstances and consequences and not antecedent conditions as in the positivist philosophy (Sango, 2013). The choice of the mixed methods design was based on the sense that it uses the strengths and similarities of both qualitative and quantitative approaches. It absolves the weaknesses of each of the research paradigms by capitalising on the strengths of both. For example, in the positivist paradigm, the assumption that all changes can be perceived as a result of the relationship between two variables (e.g. climate and vector-borne diseases) could not be accurate as correlation is not always causality. This gap can be filled by a phenomenological paradigm which tries to understand the views and reactions of the people who have been interacting with the environment over a long period of time concerning the proliferation of vector-borne diseases under some changing climate.

Punch (2011) reiterates that the mixed method design is highly pragmatic and convenient as it allows the researcher to use quantitative and qualitative techniques either interdependently or independently. Thus, it is vastly flexible and can be used in diverse research projects. While quantitative methods focus on the collection of facts, qualitative methods place prominence on the meanings derived from the facts.

Figure 3 summarises the methodological approach used in this study.

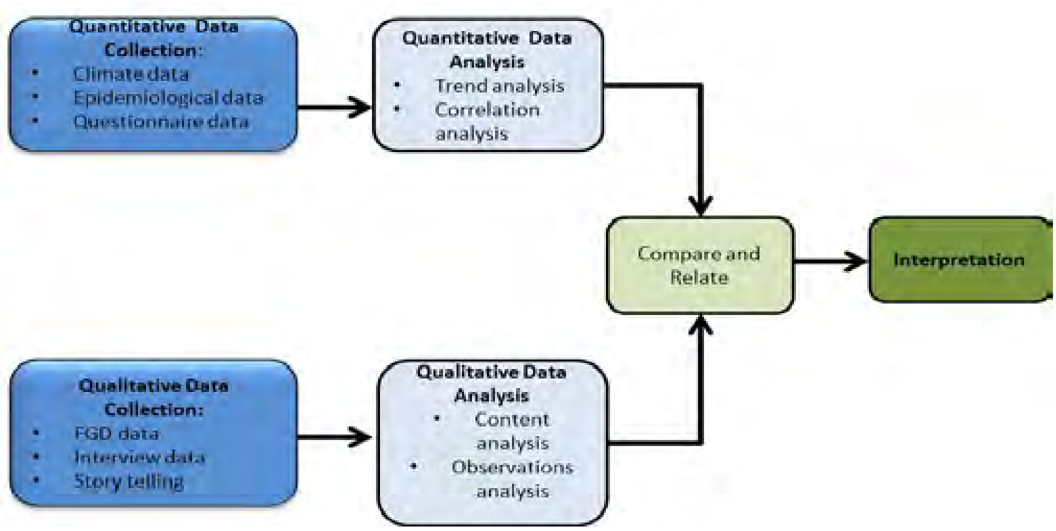

Figure 3: Mixed methods approach

Study site selection and Sampling methods.

A mix of clustered random, purposive and chain referral sampling techniques was used as strategies for identifying respondents in this study. The residential suburbs were treated as clusters from which households were randomly selected to participate in the study. Purposive sampling was used to identify medical practitioners who had knowledge of the vector-borne diseases in the city. Two climate-change experts from Masvingo City Council and Ministry of Health and Child Care were also purposively identified. The chain-referral sampling strategy was adopted when one medical practitioner would identify another expert of vector-borne diseases not known to the research team.

Data Sources and collection methods

Questionnaire surveys

Questionnaire surveys were administered in residential suburbs at the household level. It is generally understood that local communities are aware of the changes that have taken place in their localities over time. Thus, a survey questionnaire was used to gather information on the impact of climate-change on the proliferation of vector-borne diseases. This information complemented data obtained through direct observation. Adoption of questionnaire surveys as a tool for data collection was based on its robustness in collecting both quantitative and qualitative data from subjects that have experienced changes over time. Stimpson (1996), opines that questionnaire surveys provide snapshots of existing conditions at specific localities. In addition, we found it to be a cheap and cost effective tool for data collection. This supports the ascertion by several scholars (Mapira, 2015; Lincoln & Guba, 2000; Ian, 1996) that questionnaires remain one of the cheapest methods to collect data that can be useful across various disciplines.

Questionnaire surveys contain close-ended and open-ended questions. Close-ended questions require objective answers selected from a provided list while open-ended questions allow respondents to express their views with high flexibility. The surveys used in this study contained both close and open-ended questions. With these, the survey managed to capture quantitative data as confirmed by Bailey (2007). Thus, we collected dataand transformed it into data that can be analysed using statistical procedures. Thus, answers to particular questions can be organised such that parametric and non-parametric tests can be computed.

Key Informant Interviews

Key informant interviews were conducted to infer data from important institutions and individuals involved in the management of health and climate-related issues. Thus, the climate-change office and Meteorological Services Department (MSD) were regarded as important stakeholders in climate-change. Furthermore, the Ministry of Health representatives were regarded as important to provide insight into the proliferation of vector-borne diseases in the city. An interview guide, which is basically a set of preconceived questions, was used to guide the interview process. The process enabled the interviewer to have dialogue with the interviewees as postulated by Fontana and Frey (1994). Using the semi-structured interviews, the views of the key informants were fully characterised based on their knowledge, expertise and experience with regards to the impact of climate-change on vector-borne diseases.

Secondary statistical data

Rainfall and temperature data was obtained from weather stations within and near Masvingo Urban which are run by the Zimbabwe Meteorological Services Department (ZMSD). However, the dataset obtained from ZMSD was incomplete. The last records from the data was in 2010 yet the research needed data for a period spanning to 2018. Other data was then obtained from the National Climate Data Centre (NCDC) which is managed under National Oceanic and Atmospheric Administration (NOOA) programmes for preserving, monitoring and provision of climate and historic weather data (www.ncdc.noaa.gov). The NCDC had records spanning throughout the period under assessment. Before the two sets were combined, the researcher validated the data sets to assess whether the two systems recorded similar data from the same station. This was done using regression analysis of available data from the two data sources. Spearman rank correlation coefficient analysis revealed a strong positive ($r = 0.95$) relationship between the two data sets with 0.91 as the coefficient of determination. Figure 4 shows the regression results of ZMSD by NCDC data.

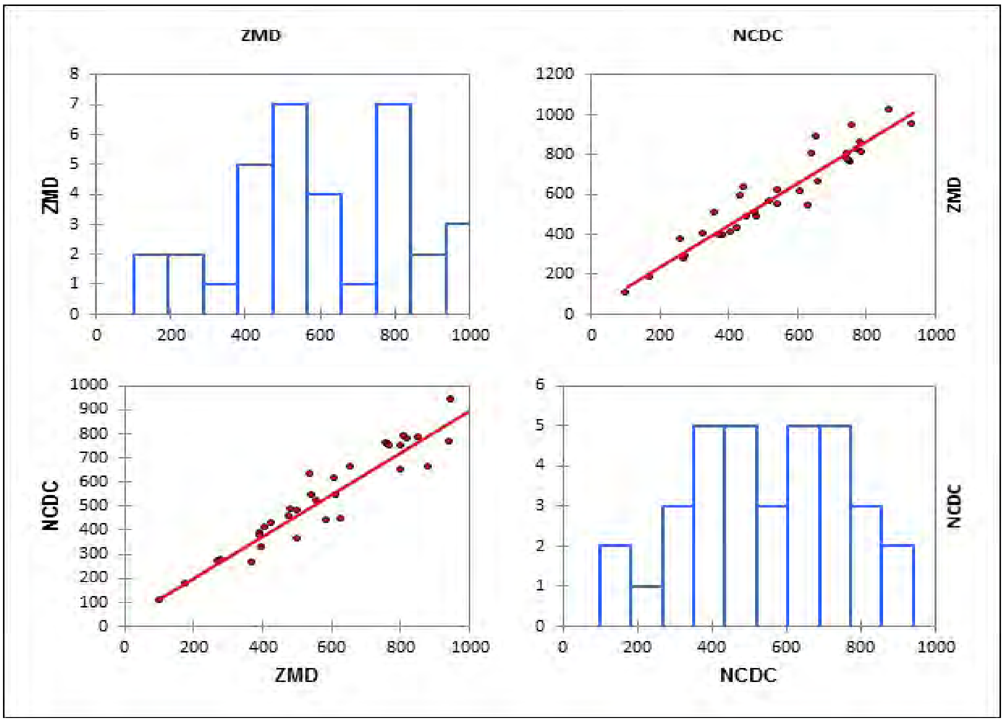

Figure 4. relationship between NCDC and ZMD meteorological records

Given the strong positive relationship between the two data sets, the data from the two sources were combined and used for the analysis of climate-change in the study. Table 1 shows the climatic variables that were analysed in this study.

Table 1. Climate-change variables

Climate-change Variable	Abbreviation
Monthly mean maximum temperature	MMMT
Monthly mean temperature	MMT
Maximum temperature of the warmest month	MTWM
Minimum temperature of the coldest month	MinTCM
Total annual precipitation	TAP
Mean monthly precipitation	MMP
Precipitation of the warmest quarter	PWQ
Seasonal mean precipitation	SMP

Besides meteorological data, statistical epidemiological data on vector-borne disease temporal and spatial patterns was obtained from the Masvingo Provincial Hospital, **seven** local public clinics and **five** private health facilities in Masvingo Urban. From these, historical data on vector-borne disease cases was obtained.

Data analysis procedures

Analysis was performed using different methods and procedures based on the type of data and the objective being addressed. Both exploratory and confirmatory data analysis approaches were used.

Normality tests

Rainfall and temperature data, which constituted the time series data, were tested using the Kolmogorov-Smirnov test to ascertain whether they deviate from a normal distribution or not. This helped in determining whether the data satisfy assumptions of parametric or non-parametric statistical analysis methods (Chikodzi and Mutowo, 2014). Parametric tests are applicable when the data assumes a normal distribution; otherwise, it is ordinarily sensible to use non-parametric tests (Lettenmaier, 1976; Hirsch *et al.,* 1993). In this study, therefore, parametric statistical analysis methods were used.

Autocorrelation and Pre-whitening

Before trend analysis using the non-parametric Mann-Kendal test, meteorological data was initially tested for auto-correlation to determine the need for pre-whitening. Auto-correlation is the correlation of a time series with its past and future values (Hamed and Rao, 1998). Its detection would require the data to be pre-whitened. Hamed and Rao (1998) noted that geophysical time series are frequently auto-correlated because of inertia or carryover processes in the physical system. This complicates the application of statistical tests by reducing the number of independent observations thereby increasing the chances of detecting significant trends even if they are absent and vice versa.
Pre-whitening is the process of removing undesirable auto-correlations from time series data before analysis. Thus, the data was pre-whitened in Paleontological statistics (PAST 3.0) software using the Autoregressive Integrated Moving Average (ARIMA) model (Hamed and Rao, 1998). The ARIMA model performs time series forecasting and smoothening and project the future values of a series based entirely on its inertia. It considers trends, seasonality, cycles, errors and non-stationary aspects of a data set when making forecasts. It reduces residuals to white noise in the time series thereby removing the possibility of finding a significant trend in the Mann-Kendall test when there is no trend (Von Storch, 1995).

Trend testing

The study tested if there was a significant change in precipitation and temperature variables over a 40-year period (1974-2014) using the Mann-Kendall (MK) trend test which was proposed by Mann (1945) and further developed by Kendall (1975). The MK test is a non-parametric method commonly employed to detect monotonic trends in a series of environmental, climate or hydrological data (Pohlert, 2016). The test is simple, robust, can cope with missing values, and seasonality and values below the detection limit (Hirsch *et al.,* 1993; Dietz and Kileen, 1981). An add-in of Microsoft excel, XLSTAT 2015 was used to carry out this test due to its ability to take into account and removing the effect of auto-correlations.

Using the Mann Kendall test, the null hypothesis, H_0, is that there is no trend in the series. Thus, the data comes from a population with independent realizations and is identically distributed. The alternative hypothesis, H_1, is that there is a trend in the series. Thus, the data follows a monotonic trend. The Mann-Kendall test statistic was calculated using Equation 1:

$$S=\sum_{k=1}^{n-1}\sum_{j=k+1}^{n} \operatorname{sgn}(X_j-X_k) \qquad [1]$$

where S is the Kendall score. Sgn (x) = {1 if x>0, 0 if x = 0, -1 if x <0} (Mann, 1945)

Determination of period prevelance rate

The period prevelance rate for Malaria was determined using the following formula:

revalence=(Number of Cases)/(Total Population)*100 [2]

RESULTS AND DISCUSSIONS

Climate-change trends in Masvingo City

The 40-year temperature and rainfall data shows that climate-change is occurring in Masvingo Urban. Table 2 shows data and descriptions of trends for 8 bioclimatic variables.

Table 2: Bioclimatic variables explaining climate-change in Masvingo city of Zimbabwe.

Climate-change Variable	m + c	P- Value	Description of trend
MMMT	0.0327-38.399	0.001	Significant change/ increasing trend
MMT	0.0187-17.651	0.002	Significant change/ increasing trend
MTWM	0.863-89.854	0.011	Significant change/ increasing trend
MinTCM	-0.0445+89.269	0.043	Significant change/Declining trend
TAP	-4.7883+10116	0.049	Significant change/Declining trend
MMP	0.4203+88534	0.046	Significant change/Declining trend
PWQ	3.4206+7137.3	0.048	Significant change/Declining trend
SMP	4.4614+60021	0.323[a]	Not significant/ Declining trend

[a] Trend not significant at α=0.05   m+c is the regression equation.

Seven out of the 8 assessed bioclimatic variables show a significant (p<0.05) trend. Temperature-related variables such as mean monthly maximum temperatures (MMMT), mean monthly temperatures (MMT), maximum temperatures of the warmest month (MTWM) and minimum temperatures of the coldest month (MinTCM) show a generally increasing trend indicating that the atmosphere is getting warmer with time. The increases in all the temperature related variables are statistically significant. Precipitation variables such as total annual precipitation (TAP), mean monthly precipitation (MMP), precipitation of the warmest quarter (PWQ) and seasonal maximum precipitation (SMP) show a declining trend. This shows that in general, there is a decline in the amount of rainfall received in the city over time. All the precipitation-related variables show a significant trend except SMP although the trend is declining.

Temperature

Figure 4 shows 40-year trends for temperature-related variables (MMMXT, MMT, MTWM and MinTCM). The variables are important as they determine major climatic shifts over a long period of time. Given the role of temperature in biological processes, they are also important when determining the effects of climate-change on vector-borne diseases.

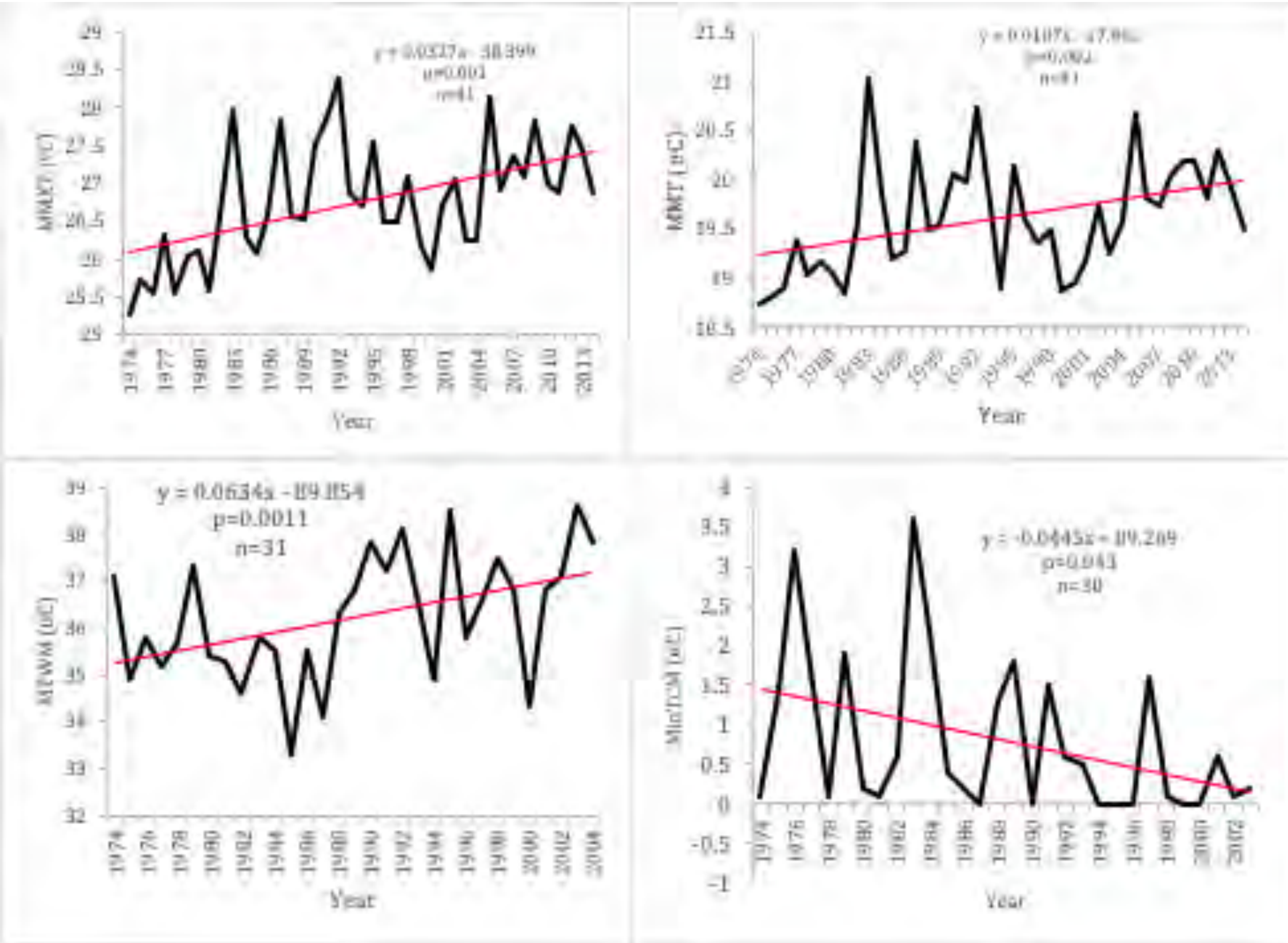

Figure 5: Temperature trends in Masvingo city, Zimbabwe.

There is a statistically significant (*p*= 0.001, α = 0.05) change in MMMXT in the city. As shown in Figure 5, the linear model presents an increasing trend. An increase of about 0.33^{0}C is estimated over the 40-year period. The MMT also shows a significantly (P=0.002 α=0.05) increasing trend over the 40 years. The estimated MMT increased by 0.27 °C over the period under study. It is also observed that the trend for MTWM has increased over time and it is statistically significant (p=0.011, α= 0.05). October is regarded as the warmest month of the year in this climatic region (Gwitira *et al*., 2013). Selection of the month was based on a preliminary analysis of temperature characteristics of all months over a thirty-year period 1974-2004. Furthermore, MTCM show that there is a significant (P=0.043; α= 0.05) change of temperature regimes in the city.

Perceptions on temperature changes
A qualitative analysis of temperature changes confirmed the validity of quantitative claims that there is a significant change in temperatures in the city. Figure 6 presents the views of local people and the percentage of respondents for each view.

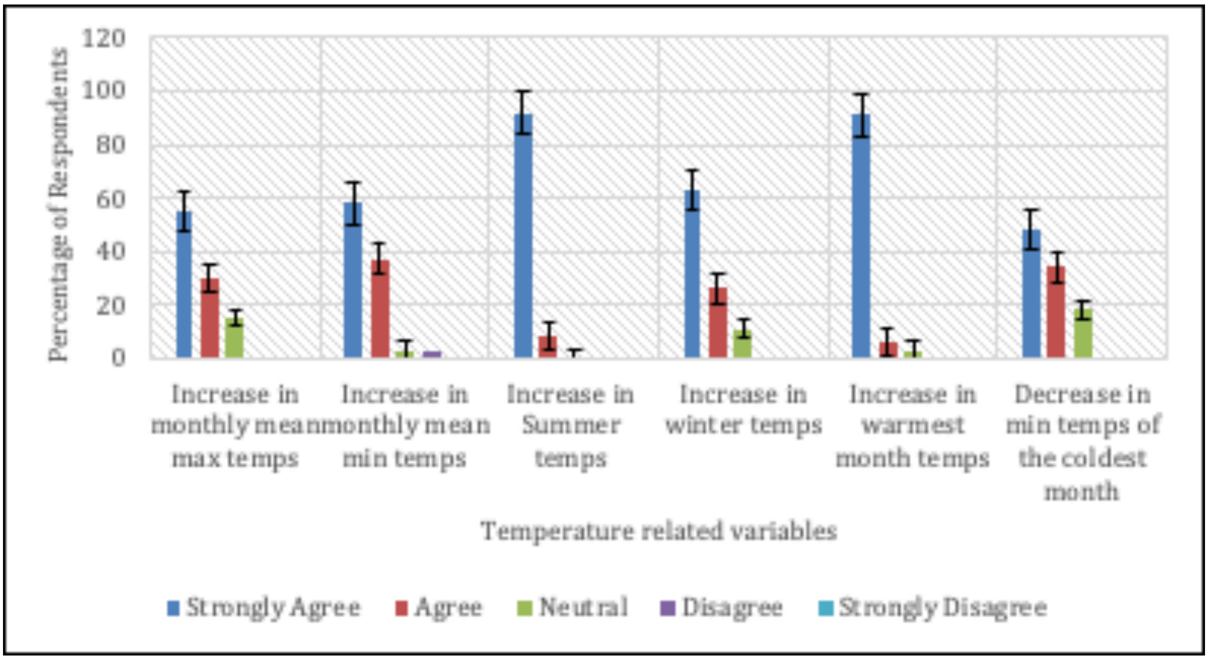

Figure 6: Perceptions on temperature changes in Masvingo city, Zimbabwe.

More than 50% of the respondents indicated strong agreement to the fact that all temperature-related variables are increasing over time. More than 20% agree with this notion while the remaining percentage is neutral. None of the respondents showed disagreement or strong disagreement with the fact that over the period under study, temperature related-variables have changed. Thus, we observed that local people feel that temperature related-variables in the city are changing over time. The people's views confirm observations made through analysis of climate data recorded over time.

Precipitation
Precipitation data in Masvingo city has been used to determine the statistical significance in the trends of different precipitation-related variables. The variables considered under precipitation include TAP, MMP, PWQ and SP. Figure 7 shows the trends for precipitation- related variables. These variables significantly depict climatic shifts over a long period of time.

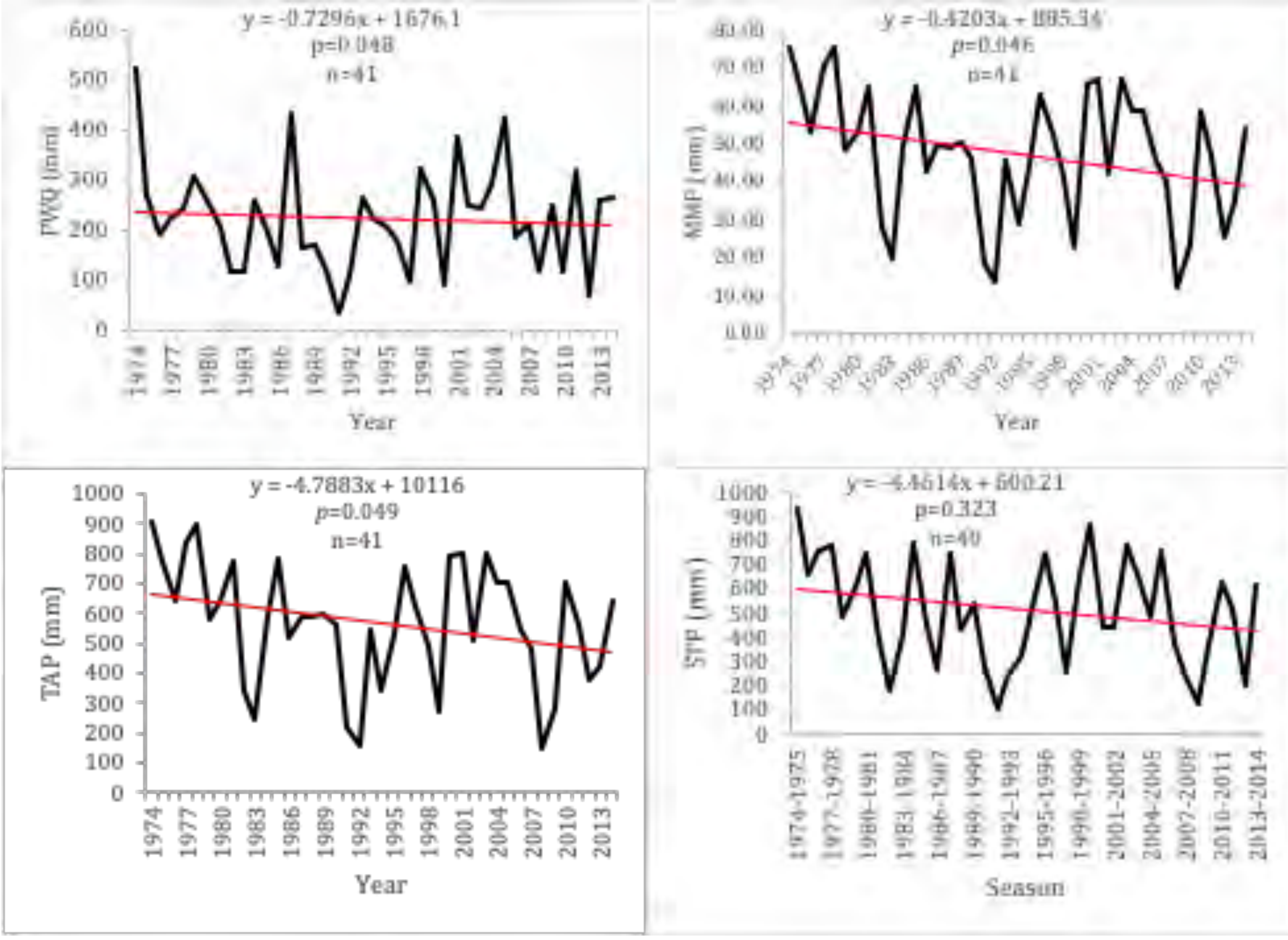

Figure 7: Precipitation for Masvingo City between 1974 and 2014.

Total annual precipitation, as the sum of all precipitation, received and recorded throughout the year, over a forty-year period shows a statistically significant (P=0.049, α=0.05) declining trend. Moreover, the monthly mean precipitation shows a significantly (P = 0.046, α= 0.05) declining trend that depicts some changing climate. The warmest quarter is the three-month period which receives the highest amount of radiation and consequently temperatures throughout the year. In the subtropical region in general and Zimbabwe in particular, this period falls between October and December. Thus, precipitation data for the warmest quarter reveal a statistically significant (P=0.048, α = 0.05) trend over a forty-year period. Precipitation data only for the rain season reveals that there is no significant (P=0.323; α = 0.05) trend in the series. However, a gradually declining trend can be observed over time.

Perceptions on Precipitation changes

Local people feel that the amount of rainfall over the period under study declined. About 73% of the respondents indicated that they strongly agree that annual rainfall totals decreased with time. Twenty percent indicated that they agree with this view while 7% were not sure. The respondents reported an increase in the severity and frequency of droughts. An increase in the intensity of floods occurring in the city was reported by 98% of the respondents. In general, variable descriptions by local people have shown that climate-change is occurring as indicated by the long-term changes in specific precipitation related variables.

The trend of vector-borne diseases in Masvingo Urban

Results show a significant ($p=0.025$, $\alpha=0.05$) increase in the cases of vector-borne diseases in Masvingo city (figure 8). It was reported through interviews that the city used not to be prone to vector-borne diseases such as malaria but due to the changes in environmental conditions, the city has become vulnerable to the disease. Malaria has been reported to be the dominant vector-borne disease followed by dengue fever.

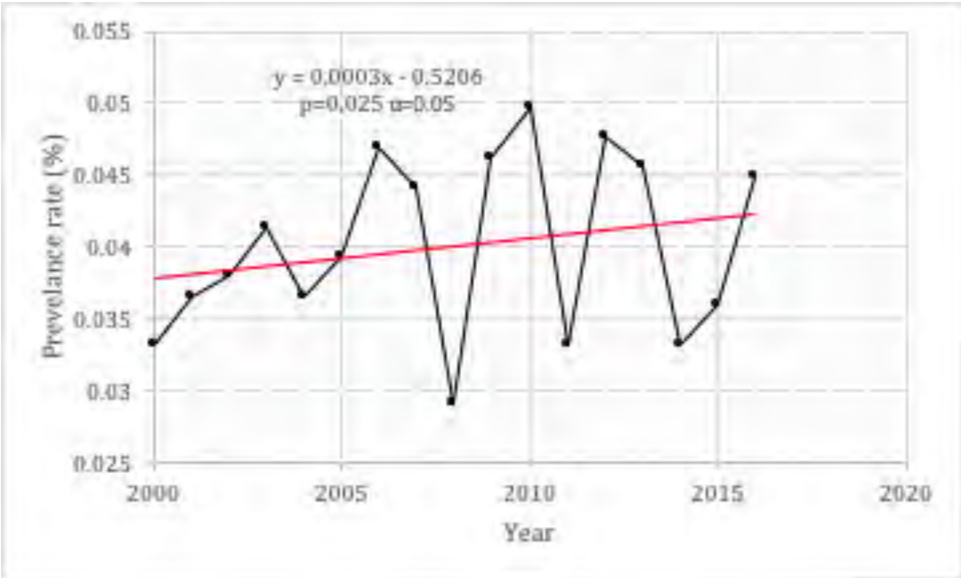

Figure 8. Trend for Malaria in Masvingo city

Figure 8 shows that over time the cases of vector-borne diseases reported in health centres have been increasing. The trend does not reflect unreported cases. The pattern is however complex, and cannot be explained by a single factor. There are many confounding variables behind the patterns. Results from focus group discussions reflect that there is a plethora of socio-economic and environmental factors that interact and modify disease spatial and temporal patterns. For example, mobility of individuals from areas where malaria is already predominant. It was reported that some of the cases reported at health centres were 'imported' from areas such as Chiredzi and Mutare. Other behaviourial patterns such as poor waste-disposal promote breeding of mosquitos. Increased rate of breeding elevates the chances of mosquito bites and consequently the probability of malaria cases. Uncontrolled agricultural activities around the city was reported as another factor which might be contributing to the increase in vector density. Swamps of mosquitos are observed in crop fields and vegetated areas. Some respondents argued that there could be a relationship between increased population density and malaria cases, indicating that as the population grows, it influences social, economic and ecological changes that may promote the occurrence of vectors that transmit diseases. However, it is a fact that temperature and precipitation regimes have a stake in the patterns given that the insect vectors and parasites that transmit pathogens favour high temperatures and wet conditions.

Relationship between temperatures and vector-borne diseases in Masvingo Urban

Although there is a deluge of factors that explain the trend of vector-borne diseases, our results indicate that mean maximum monthly temperature (MMMT) is positively correlated with vector-borne disease cases. As shown in Figure 9, there is a strong positive ($r = 0.85$, $r^2=0.85$) relationship between vector-borne disease cases and MMMT.

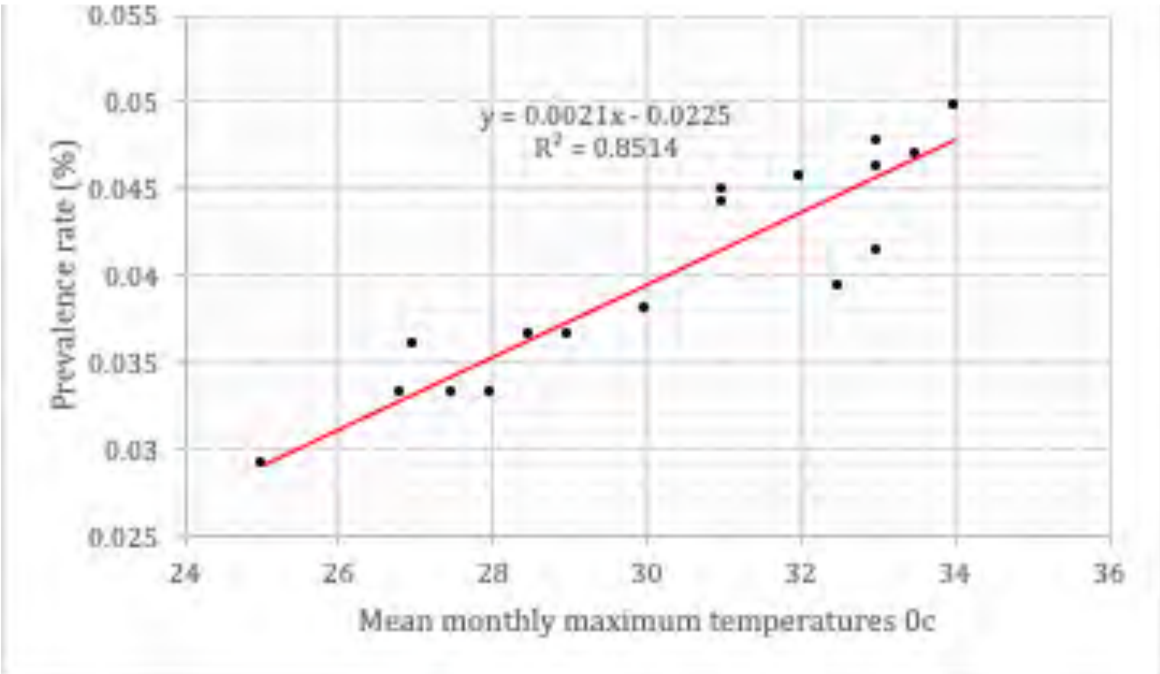

Figure 9 Relationship between Malaria prevelance and MMMT

Qualitative data has also shown the relationship between the two. More than 80% of the questionnaire respondents indicated that temperatures are increasing as well as cases of water-borne diseases.

Relationship between precipitation and malaria prevalence.

Results show that as precipitation decrease, the prevalence of malaria is increasing. However, the relationship between the prevalence of falciparum malaria and mean monthly precipitation is not very strong (r^2=0.341) (Figure 10).

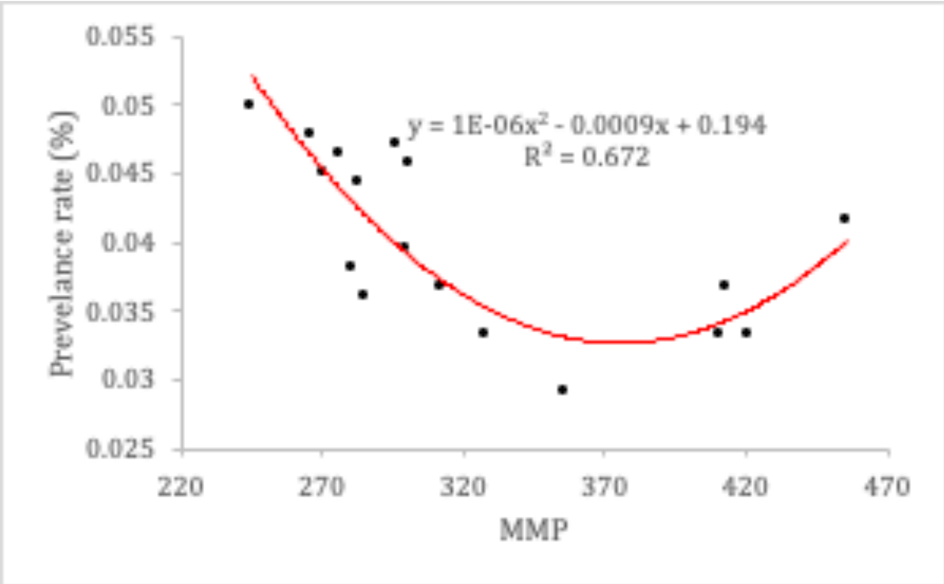

Figure 10 Relationship between Malaria prevelance and MMP

Of the 17 vector-borne disease cases considered, more than 30% were not associated with low amounts of precipitation. This points to the fact that a decrease in precipitation may not necessarily lead to an increase in disease cases. Figure 10 shows that most of the cases were associated with a monthly average precipitation of less than 320mm.

Cross correlation analysis (Table 3) of climate variables and prevalence rate shows that temperature and precipitation have a combined effect on the proliferation of falciparum malaria. Whilst there is a negative correlation between precipitation and prevalence rate, there is a positive relationship between temperature and prevalence of malaria. Temperatures ranging between 30^0C and 32^0C provide the optimum conditions for malaria cases. On the other hand, mean monthly precipitation ranging between 230mm and 420mm provide the optimum conditions for malaria case occurrence.

Table 3: Relationships between temperature, MMP and malaria prevalence

	T⁰C	*MMP*	*Prevalence*
ToC	1		
MMP	-0.39829	1	
Prevalence	0.922724	-0.58432	1

This study has shown that malaria prevalence in Masvingo Urban is partly influenced by climatic parameters. Consequently, the changes occurring in climate parameters also influence changes in the prevalence of falciparum malaria. Thus, climate-change has altered disease patterns over time. There is an increase in the number of cases of diseases as temperature increases. This observation confirms Campbell (2015)'s assertion that the changing climate, principally, the increase in temperatures, is associated with an increase in the number of vector-borne disease cases. Thus, vector-borne diseases are highly sensitive to climatic factors. Previous studies have shown that unlike other climate-sensitive health risks, such as heat-stress, or exposure to storms and floods, the influence of meteorological factors is less direct, and more diverse, both within and between individual diseases (Smith *et al*., 2014). Temperature affects the biting, survival and reproductive rates of the vectors, and the survival and development rates of the pathogens that they carry (Campbell, 2015).

Monthly mean precipitation has been shown to exert some influence on the proliferation of malaria, which is transmitted by vectors that have aquatic and humidity developmental stages. Although this study has shown that a decrease in precipitation is associated with an increase in the number of cases of malaria, previous studies (Campbell, 2015, Madeleine *et al*., 2018, Andrew *et al*., 2000) have shown that vector-borne diseases increase their abundance and spread when precipitation increases. This is because vector insects and parasites favour high temperatures and wet conditions. Madeleine *et al*., 2018 postulate that the negative effect of reduced precipitation and drought have been seen in Senegal, where *A. funestus* has virtually disappeared and malaria prevalence has dropped by more than 60% over the last 30 years. Our results could mean that other confounding variables regulate pathogen transmission besides mean monthly precipitation. Possibly, a decrease in precipitation results in a decrease in the amount of water in small water reservoirs, creating perfect conditions for mosquito-breeding and proliferation of parasites that transmit pathogens. Our study was also limited to the analysis of mean monthly precipitation and mean monthly maximum temperatures only. Other temperature and precipitation variables such as MMT, MTWM,Min TCM, PWQ, TAP and STP may also determine patterns of malaria prevalence.

It is the submission of this study that the changing climate exerts a range of more indirect effect, especially on the natural environment and on human systems. For instance, a decrease in precipitation amount may affect water-storage, land-use and irrigation practices. This may influence population movement and affect vector ecology, and human exposure to infection. Some previously relatively stable geographical distributions are now changing owing to a range of factors other than climate. For example, water reservoirs, irrigation, population movements, rapid unplanned urbanization, waste dumps and phenomenal increases in international travel and trade. These environmental and social factors may either reinforce climatic effects or counteract them. Given the strength and range of these connections, it is not surprising that there is abundant observational evidence of the effects of meteorological factors, from seasonal and interannual patterns of disease incidence in specific locations to the strong explanatory power of climate variables in accounting for the geographical distribution of faciparum malaria.

CONCLUSIONS

Climate data for Masvingo City has shown that the climate for the city is changing. The changing climate was examined to determine its impact on the spread of malaria. Using data on reported malaria cases and prevalence rate between 2000 and 2016, the current study suggests that climate-change influences the epidemiology of malaria. This study found a positive significant relationship between maximum mean monthly temperature and malaria prevalence in Masvingo City. The study also found a negative correlation between the malaria prevalence and monthly mean precipitation. However, the relationship turns to be positive with a continuous increase in mean monthly precipitation above 420mm. We conclude that climate-change influences the proliferation of malaria. However, there are other epidemiological, environmental and socio-economic factors that lead to complexities of disease patterns. There is need for further interrogation of the influence of other factors to fully comprehend and characterise the impact of climate-change. Due to the important influence of other factors, it is the position of this study that climate-change rather plays a contributory role in determining the spatial and temporary spread of malaria in the City of Masvingo.

RECOMMENDATIONS

Findings of this study reflect that climate-change contributes in modifying the temporospatial dynamics of vector-borne diseases. Notably, vector-borne diseases will spread easily under changing climatic conditions with a projected increase in temperatures and a decrease in rainfall. Furthermore, increased variability of climatic elements is likely to complicate the disease patterns. It is highly likely that many vector-borne diseases will develop in new areas. There is need to implement a cocktail of measures to build resilient communities and reduce the proliferation of vector-borne diseases.

Firstly, to effectively establish solutions to the spread of vector-borne diseases due to climate-change there is need for multivariate analysis to ascertain the contribution of all other factors affecting disease-transmission and clinical outcomes. Currently, there is a paucity of scientific information which guides the level and mode of interventions related to climate-change and health systems. The fraction of temporospatial dynamics in vector-borne diseases attributable to climate-change at the moment remains veiled in obscurity. This is an impediment to evidence-based health policy change. Thus, there is a clarion call for governments and interested stakeholders to initiate and support scientific research into vector-borne disease dynamics and the factors that influence them.

Secondly, in view of the impending burden on the health sector due to proliferation of vector-borne diseases, there is need for government and other stakeholders to invest in the health system to deal with new infections and complicated disease patterns. Investment could be in the form of training vector-borne disease specialists, equipping the existing health facilities with information and resources that will enable them to contain complicated disease patterns and establishing new health centres that specialise on insect-borne diseases.

Thirdly, building community resilience and adaptive capacity will significantly reduce the impact of complicated disease patterns. There is a need for an education campaign on vector-borne diseases and the need to reduce the creation of environments that are conducive for the development of the vectors. The capacity of communities to prevent vector bites will be of paramount importance. There is also a need to mobilise communities to develop community-based methods of protecting against vector-borne diseases.

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CHAPTER 09

THE IMPACT OF CLIMATE-CHANGE AND FISHING EFFORT ON KAPENTA CATCHES IN LAKE KARIBA

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Source: https://revision.co.zw/fishinglake-kariba/

ABSTRACT

Climate-change is negatively affecting ecosystems globally, and freshwater ecosystems are greatly susceptible. Lake Kariba, a man-made reservoir shared by Zambia and Zimbabwe, was created in 1958. In 1967/68, the Lake Tanganyika sardine, Limnothrissa miodon, was introduced into the lake, and by 1974 was being commercially exploited. The total annual catch steadily rose from 1974 to 1990, but has since undergone a gradual decrease. A number of recent studies have attributed the decrease in catches to climate-change with some disagreeing and attributing the decrease to fishing effort. The purpose of this study was to assess the relationships of L. miodon catches with climate variables, lake level and fishing effort and determine the effects of climate-change and fishing effort. We analysed trends in rainfall, temperature and lake water level data from 1964 to 2018, and fish catches data (total annual catch, fishing effort, and catch per unit effort (CPUE) from 1974 to 2018. Between 1964 and 2018, maximum atmospheric temperature around Lake Kariba increased at a rate of 0.117ºC/year, whilst minimum temperature and water levels decreased by 0.051ºC/year and 0.015 m/year respectively. Fishing effort increased by 4578.83 nights-fished/year, whilst CPUE decreased by 0.0078 tonnes/night-fished/year. Our analysis shows that fishing effort, maximum temperature and water level had a significant negative impact on catches. We conclude that the increase in fishing effort has been a major factor in the decline of L. miodon catches in Lake Kariba, which has been worsened by warming of the climate.

Keywords: Climate, Lake Kariba, Fisheries

INTRODUCTION

Climate-change is one of the most critical and urgent global challenge of this millennium. The Earth's climate is changing much faster than normally occurs naturally, primarily due to human activities (Intergovernmental Panel on Climate Change [IPCC], 2013, 2014). Rapidly rising temperatures, new precipitation patterns, and other changes are transforming ecosystems at fast rates, affecting biodiversity and many aspects of human society. People, whether in rural settings or in cities, have a close relationship with nature and biodiversity, which involves food, living space, recreation, spiritual connectedness, health, clean air and water. The benefits that people everywhere get from nature are numerous, interlinked in complex ways and have proven difficult to quantify. Understanding the impact and effects of climate-change is essential since climate-change alters the relationships between people and nature. The present chapter investigates the effects of climate-change and fishing pressure on the *Limnothrissa miodon* fishery on Lake Kariba, a man-made reservoir shared by Zambia and Zimbabwe.

Fresh-water ecosystems and their constituent species are greatly vulnerable to climate-change, because warming, volatility, sea-level rise, and acidification, directly affect fresh water organisms in some profound way (Kaufman, 2019). The impact of climate-change on freshwater ecosystems, especially fish production, is of great concern due to potential disruption of the livelihoods of communities dependent on fisheries resources. Fisheries are important sources of food, nutrition, income and livelihoods for hundreds of millions of people globally (Food and Agriculture Organization of the United Nations [FAO], 2016a). Inland capture fisheries are an important source of fish for several countries in Africa, which accounts for 25% of global catches (FAO, 2018). In 2016, fish production from inland capture fisheries was 11.6 million tonnes, which was 12.8% of total marine and inland catches (FAO, 2018). In terms of employment, de Graaf and Garibaldi (2014) estimated that the fisheries sector employs more than 12 million people either as full-time or part-time fishers and processors.

Fresh waters have over the years experienced decline in biodiversity, much greater than those in the most affected terrestrial ecosystems. Dudgeon *et al*. (2006) review and list the major threats under five headings: (i) over-exploitation, (ii) water pollution, (iii) flow modification (iv) destruction or degradation of habitat and (v) invasion by exotic species. Reid *et al*. (2019) note the further deepening of the fresh-water biodiversity crisis, and documented twelve more emerging crisis, comprising, (i) changing climate; (ii) e-commerce and invasions; (iii) infectious diseases; (iv) harmful algal blooms; (v) expanding hydropower; (vi) emerging contaminants; (vii) engineered nanomaterials; (viii) microplastic pollution; (ix) light and noise; (x) fresh-water salinisation; (xi) declining calcium; and (xii) cumulative stressors. Globally, many fish stocks have undergone population declines, with over-exploitation identified as a major driver (Reynolds, Dulvy, & Robert, 2002). Thus, the effects of climate-change can deepen the burden to fisheries that are currently being threatened by many other stress factors.

Lake Kariba was created by the damming of the Zambezi River at the Kariba Gorge in December 1958. The lake reached its maximum retention level in September 1963 (McLachlan & McLachlan, 1971). *Limnothrissa miodon* (locally known as kapenta) was introduced into Lake Kariba in 1967/68 from Lake Tanganyika (Bell-Cross & Bell-Cross, 1971), so as to fill the pelagic niche of the newly-created lake since none of the indigenous Zambezi riverine fish fauna show potential to occupy the pelagic environment (Mandima, 1999). After its introduction into the lake, kapenta quickly established commercially fishable stocks, commercial exploitation commencing by 1974 and according to the FAO (2016b), the kapenta fishery accounts for over 90% of Zimbabwe's total capture fishery landings. Early catches were so spectacular to such an extent that many viewed the fishery as a guaranteed source of quick profit. However, over the last two decades, there have been a sharp decline in kapenta catches, and the fishery is no longer as lucrative as it used to be. Several reasons have been advanced to explain the decline in kapenta catches which include over-capitalisation and the effects of climate-change.

Climate-change projections for Sub-Saharan Africa point to a warming trend, particularly in the inland subtropics, frequent occurrence of extreme heat events, increasing aridity, and changes in rainfall, with a particularly pronounced decline in southern Africa and an increase in East Africa (Serdeczny *et. al*., 2017). Unganai (1996) who analysed ambient temperature data from nine stations across Zimbabwe, obtained over a 60-year period from 1933 to 1993, found that the national annual minimum temperature trend decreased, whilst there was a warming trend in maximum temperatures. At national level, maximum temperatures increased by up to 0.8°C, with maximum temperature for most stations increasing by 0.4 to 0.6°C, and minimum temperature decreasing by 0.2 to 0.4°C (Unganai, 1996). These changes are likely to have an impact on fish production.

The impact of climate-change has been reported in some African lakes. According to Cohen *et al*. (2016), the ongoing declines in fish catches in Lake Tanganyika can be explained by climate warming. Similarly, on Lake Kariba, the decline in fish catches, especially those of kapenta, have, according to Magadza (2010, 2011) and Ndebele-Murisa, Mashonjowa and Hill (2011a, b) were as a result of climate-change. Ndebele-Murisa *et al*. (2011a) analysed rainfall, lake level, and temperature data from 1964 to 2008, and data on evaporation from 1963 to 1999. Using moving averages analysis, they report that rainfall declined at a rate of 0.63 mm per year, which equated to a decrease of about 27.1 mm from 1964 to 2008. Furthermore, they report that there were significant increases in both minimum and maximum atmospheric temperatures around Lake Kariba, which increased by about 3.29°C and 3.58°C respectively, and a significant increase in the evaporation rate of 0.14 mm per year. Using general linear models, Ndebele-Murisa *et al.* (2011a) note that all climatic factors (rainfall, temperature, and evaporation) and lake level could explain the decrease in kapenta catches in Lake Kariba, with water levels having the greatest impact, followed by maximum temperature, evaporation and rainfall. Moreover, since they found that water levels were significantly associated with temperature and rainfall, they concluded that nutrients, which are influenced by water levels, and climate particularly maximum temperature, are the primary determinants of kapenta production in Lake Kariba.

Magadza (2011) used linear regression to analyse temperature data from 1965 to 2000, and found that both minimum and maximum atmospheric temperatures for the September/October/November season increased significantly, at a rate of 0.0446°C and 0.0526°C per year respectively, which were used to give an estimate of mean increase in temperature of 0.048ºC per year. This was then used to give a 100-year warming estimate of 4.8 ºC for the Lake Kariba area. Magadza (2011) concludes that there has been a warming trend around Lake Kariba, with seasonal rates 2 ºC above the 1990 baseline that according to Parry *et al*. (2007) is likely to cause significant ecosystem changes. Furthermore, Magadza (2010, 2011) notes that the changes in climate have resulted in Lake Kariba warming at a rate of 0.62 ºC between 1965 and 1990, resulting in a reduction in the depth of the epilimnion, the upper and generally more productive water layer of the lake, as well as a strong and stable stratification. Magadza (2011) suggests that due to global warming-induced thermal changes to the lake, the phytoplankton community has changed from one dominated by green algae (Chlorophyceae) to one largely comprised of blue-green algae (Cyanophyceae). Cyanophycea, unlike green algae, are quite resistant to digestion by zooplankton grazers (Porter, 1973; Haney, 1987; Lampert, 1987), can suppress the growth of other algae (Keating, 1978) and some strains produce toxins that adversely affect a broad range of organisms including protozoa, plants, invertebrates and vertebrates (Oberemm *et al*. 1999; Falconer, 2013). Thus, according to Magadza (2011), the likely dominance of Cyanobacteria due to warming has resulted in reduction in entomostracan zooplankton that graze on phytoplankton and are the principal food of kapenta, and consequently the decline in kapenta catches.

There are some who have disagreed with the findings that climate-change has had a significant impact on African fisheries, with Sarvala *et al*. (2006) arguing that the declining trend in fish catches on Lake Tanganyika are largely due to changes in fishing practices and not climate. Likewise, Marshall (2012) has argued that the decrease in kapenta catches on Lake Kariba has not been due to the effects of climate-change but rather due to increase in fishing pressure. Fishing is one of the major factors that has modified aquatic ecosystems (Jackson *et al*., 2001), and high fishing pressure can enhance the risk of a population collapse (Shoener, Spiller, & Losos, 2001). The studies by Magadza (2011) and Ndebele-Murisa *et. al.* (2011a, b) argue that fishing effort/pressure has had no significant impact on kapenta catches on Lake Kariba. Ndebele-Murisa *et al.* (2011a, b) rule out fishing pressure on the basis of kapenta catch and effort data from the Zimbabwean side of Lake Kariba. They note that between 1992 and 2002, there was a decrease in the number of fishermen on the Zimbabwean size of Lake Kariba, and hence a reduction in fishing effort. Magadza (2011) analyses catch data from 1979 to 2000 and suggests that there was no trend in relation between effort and catch per unit effort.

Thus, the debate on the effects of climate-change and fishing effort on kapenta catches in Lake Kariba is still to be resolved. This study explored trends in climate variables (minimum and maximum temperature, rainfall) and lake level since the early years of Lake Kariba, as well as trends in total kapenta catch, fishing effort and catch per unit effort since commercial exploitation of kapenta began. The aim of the study was to assess the relationships that kapenta catches on Lake Kariba have with climate variables, lake level and fishing effort, and hence determine the effects of climate-change and fishing effort on kapenta catches.

DESCRIPTION OF THE STUDY AREAS AND METHODOLOGY

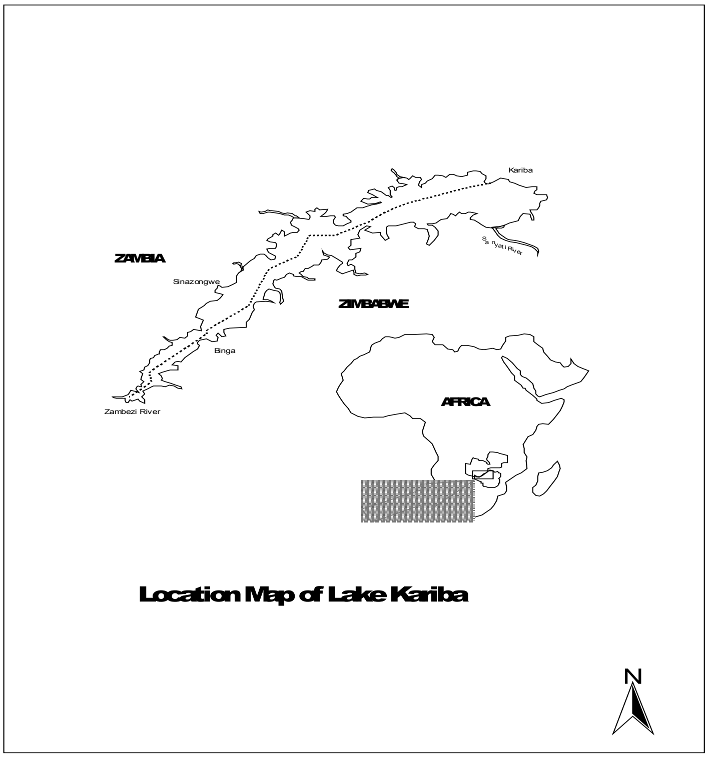
Study Area

Lake Kariba lies on the international boundary between Zimbabwe and Zambia and its main axis runs in a South West–North East direction (Figure 1). The lake, which is among the largest man-made reservoirs in the world, has a surface area of 4 364 km^2 at the normal operation level of 484 m a.s.l, a length of 276 km, an average width of 19 km and an average depth of 29 m. The Zambezi River, the main water source for the Lake, drains a catchment area of 1 193 500 km^2 above the Lake. It receives water from much of Zimbabwe, Zambia, eastern Angola, and a small part of Botswana (Marshall, 1982). The lake hosts two important commercial capture fisheries which are the inshore gill net-fishing industry and the pelagic semi-industrialised fishing industry. The latter is based on the exploitation of *L. miodon*.

Research Methods

Data Sources and Collection Methods

Climate data from January 1964 to December 2018 comprising monthly averages for rainfall, minimum and maximum temperature were obtained from the Meteorological Services Department of Zimbabwe. Average monthly lake level data for the same period were obtained from the Zambezi River Authority (ZRA), whilst the data for Kapenta fishing effort and annual catches for both Zambia and Zimbabwe were supplied by the Lake Kariba Fisheries Research Institute, a research unit of the Zimbabwe Parks and Wildlife Management Authority (ZPWMA). Commercial kapenta-fishing on Lake Kariba commenced on the Zimbabwean side of the lake in 1974, and in 1982 on the Zambian side. Thus, the fishing data obtained was from 1974 to 2018 and 1982 to 2018 for the two countries, respectively. The data from the two countries was combined to obtain the total kapenta catch (in tonnes) for each year and the total fishing effort (nights of fishing). The annual total fishing effort was obtained by calculating the total time of night-fishing by all the kapenta fishing rigs for that year.



Location Map of Lake Kariba

Figure 1: Map of Lake Kariba

2.2.3. Data Analysis Procedures

The data was analysed using R version 3.6.1 (R Core Team, 2019). We used the TTAinterfaceTrendAnalysis (v 1.5.5) package (Devreker & Lefebvre, 2019) to perform temporal trend analysis for rainfall, minimum and maximum temperature, lake level, total catch, fishing effort, and the catch per unit effort (CPUE) and obtain a Sen's slope for the estimate of linear rate of change. The change-point package (Killick, Haynes, & Eckley, 2016) was used to detect change-points in the seven variables. Generalised additive modelling (GAM) was applied to determine the relationships that Kapenta CPUE had with rainfall, lake level, temperature and fishing effort using the gam package (Hastie, 2019).

RESULTS AND DISCUSSION

Changes in climatic conditions in Kariba environs

Rainfall trend

The observed monthly rainfall and trend in annual means for Kariba from 1964 to 2018 are shown in Figure 2. Although there were periods of relatively low rainfall such as 1983 – 1984 and 1995 – 1996 (Figure 2), there was no change in overall trend in rainfall during the 55-year period (Table 1), and generally, the mean annual rainfall for the period was 61.3 mm.

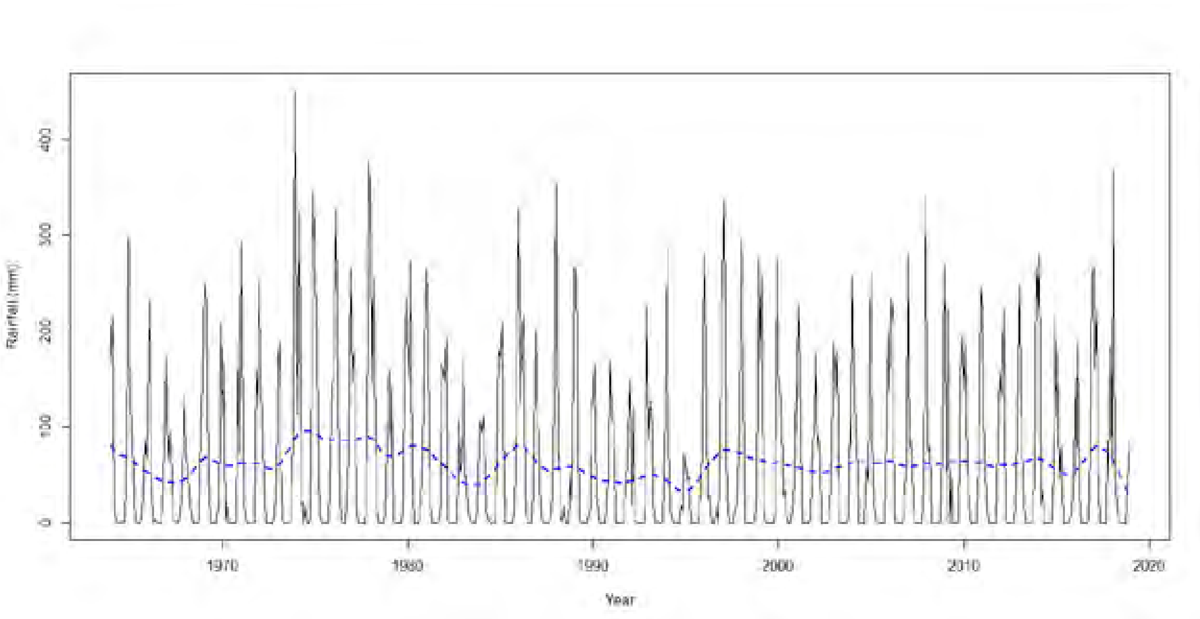


Figure 2: Time series of observed monthly rainfall and the trend in annual mean rainfall (dashed line) for Kariba from 1963 to 2018.

Table 1. Lake Kariba trend in rainfall, minimum and maximum temperatures from 1964 to 2018.

Variable	Trend (sen slope)	p value
Rainfall (mm)	0.000	>0.05
Minimum temperature (ºC)	-0.0511	0.0009
Maximum temperature (ºC)	0.1174	0.0000
Lake level (m)	-0.0149	0.0187

Temperature changes

Figure 3 shows the observed monthly minimum and maximum temperatures as well as the trends in annual means for the two variables. There were significant changes in trends ($p < 0.05$) for both minimum and maximum temperature over the 55-year period (Table 1). Minimum temperature decreased at a rate of 0.051 ºC/year (or -0.0029% ºC/year), whilst maximum temperature increased at a rate of 0.117 ºC/year, which was equivalent to an increase of 0.0037% ºC/year. Thus, between 1964 and

2018, the minimum temperature decreased by about 2.8 °C, whilst maximum temperature increased by about 6.4 °C. Change-point analysis showed that for both minimum and maximum temperatures, the change occurred around 1984 and 2014. The average minimum temperature for the period 1963 to 1984 was 18.28 ± 4.52 °C, whilst for the period 1985 to 2014 it was 15.32 ± 4.61 °C, and 19.51 ± 4.28 °C from 2015 to 2018. The averages for maximum temperature were 30.43 ± 2.85 °C for the period 1963 to 1984, was 35.73 ± 3.30 °C for 1985 to 2014, and 32.33 ± 3.06 °C from 2015 to 2018.

Lake water level

Trend analysis shows that from 1964 to 2018, lake level (Figure 4) underwent a significant decrease ($p < 0.05$) of about 0.015 m/year (Table 1). Generally, from 1964 to 1982, there was an increasing trend in lake level, followed by a sharp decrease and low levels from 1983 to 1998. Low lake levels were also recorded from 2005 to 2007 and 2015 to 2018, whilst periods of high-water levels were 1964 to 1982, 1999 to 2004 and 2008 to 2014 (Figure 4). The mean annual lake level for the period 1983 – 1998 was 479.56 ± 1.74 m compared to 485.9 ± 1.04 m and 485.08 ± 1.33 m for the periods 1974 – 1982 and 2008 – 2014, respectively.

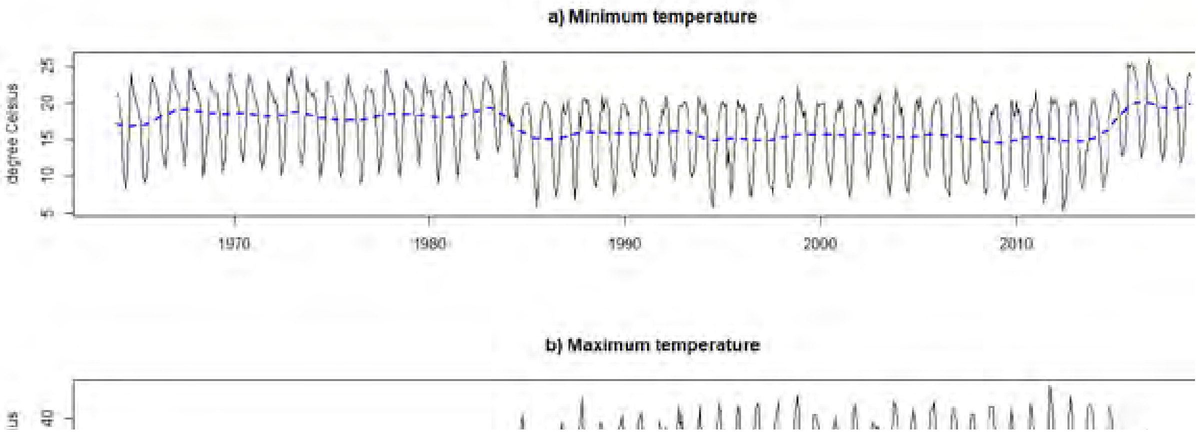


Figure 3: Time series of observed monthly minimum (a) and maximum (b) atmospheric temperatures and their annual mean trends (dashed line).

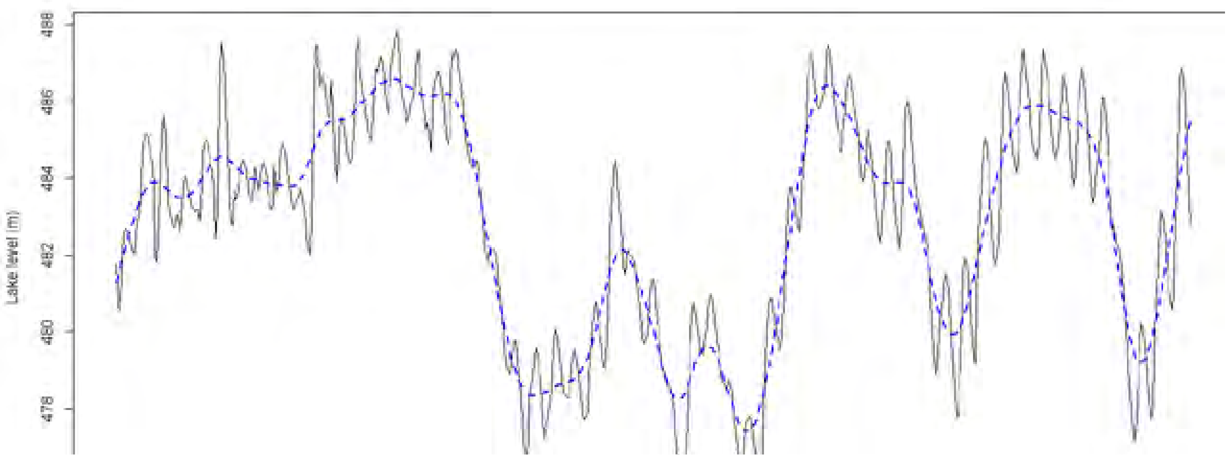


Figure 4: Time series of observed monthly lake levels and the trend in annual mean (dashed line) from 1964 to 2018.

Change in kapenta catches

The trends in total catch, effort and the catch per unit effort for kapenta in Lake Kariba from 1974 to 2018 are shown in Figure 5. The total catch increased gradually from 1974, with peak catch obtained in 1990, followed by a gradual decrease (Figure 5). Change-points in total catch occurred in 1977, 1979, 1984, 1994, and 1998. The period with the lowest average total catch (840.50 ± 279.67 tonnes) was from 1974 to 1977, with the highest mean catches (27,826.00 ± 2,130.90 tonnes) obtained from 1985 to 1994. From 1995 to 1998, the mean total catch was 24,231.75 ± 822.35 tonnes, which then fell to about 17,980.09 ± 2,354.64 tonnes between 1999 and 2018. The overall trend in total catch for the 45-year period was not significant ($p > 0.05$) (Table 2).

Kapenta-fishing effort increased from 1974, with change-points recorded in 1977, 1979, 1983, 1986, 1990, 2009 and 2013 (Figure 5). The mean fishing effort was 1,713.25 ± 915.15 nights fished between 1974 and 1977, had risen to 80,520.33 ± 4,201.22 nights fished between 1984 and 1986, and was 172,161.25 ± 3,478.64 and 245,721.40 ± 27,977.07 nights of fishing for the periods 2010 to 2013, and 2014 to 2018, respectively. Generally, there was a significant ($p < 0.05$) positive trend in fishing effort of 4,578.83 nights of fishing per year from 1974 to 2018 (Table 2). Over the same period, the change in the trend in CPUE was significant ($p < 0.05$), and decreased at a rate of 0.0078 tonnes/nights of fishing/year (Table 2). Change-point analysis showed mean CPUE from 1974 to 1979 was 0.517 ± 0.020 tonnes/nights of fishing/year, had decreased to 0.269 ± 0.031 between 1980 and 1992, and was 0.066 ± 0.008 tonnes/night/year from 2015 to 2018 (Figure 5).

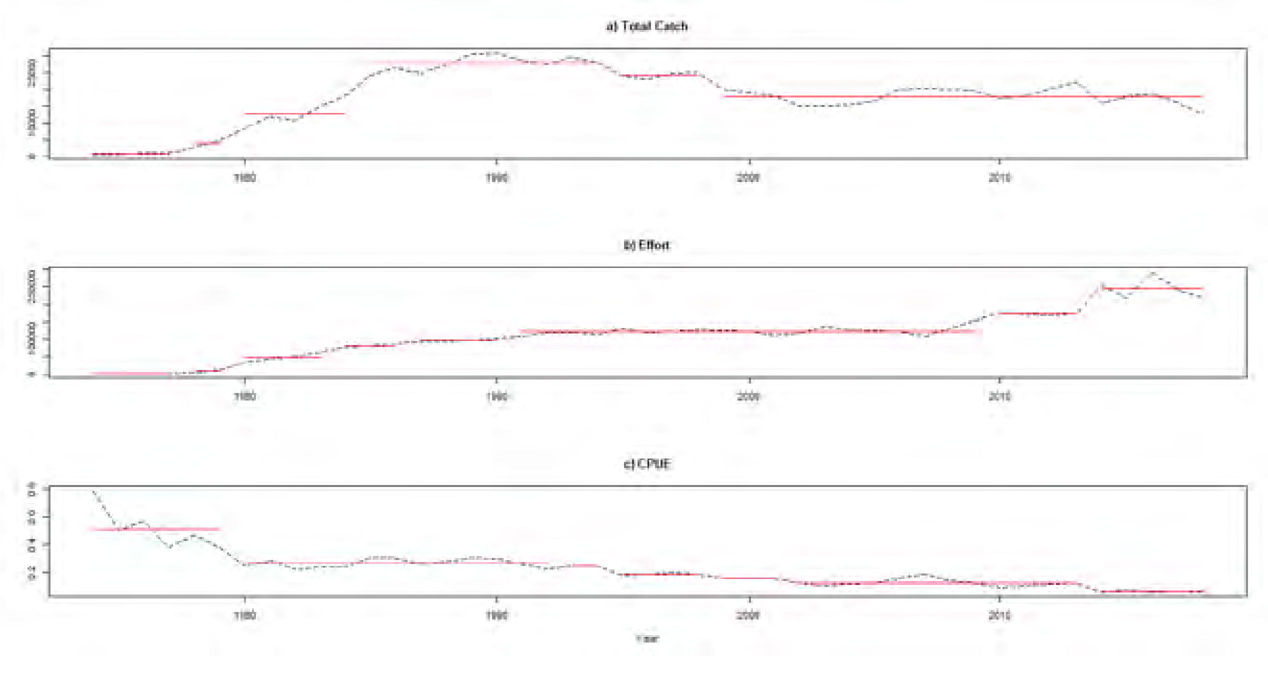


Figure 5: The trends in total catch (tonnes), effort (nights of fishing) and the CPUE (tonnes/night) in Lake Kariba from 1974 to 2016. The breaks in the horizontal lines show change-points in the trends.

Table 2. Trend in total catch, fishing effort and the catch per unit effort for kapenta in Lake Kariba from 1974 to 2018.

Variable	**Sen's slope (trend)**	**p value**
Total catch (tonnes)	145.15	0.3044
Effort (nights fished)	4578.83	0.0000
CPUE (tonnes/night)	-0.0077	0.0000

Kapenta-catches and relationship with fishing effort, lake level, rainfall and temperature
Analysis of the relationship between kapenta CPUE with fishing effort, lake level, rainfall and temperature using Generalised Additive Modeling showed that the CPUE was significantly related to fishing effort, lake level and maximum temperature (Table 3). Fishing effort and lake level had significant parametric linear relationships with CPUE, whilst fishing effort also together with maximum temperature had significant non-linear relationships with CPUE. As fishing effort increased to about 150,000 nights of fishing, there was a significant quadratic decrease in CPUE, but increase in effort beyond 150,000 nights of fishing was associated with a significant but linear decrease in CPUE (Figure 6). An increase in maximum temperature from below 30 °C to about 32 °C was associated with quadratic decrease in CPUE, which was followed by another quadratic but slower rate of decrease in CPUE as temperatures rose beyond 35 °C (Figure 6). Below lake levels of about 481 m, the CPUE was relatively constant, but underwent a comparatively fast but linear decrease as lake levels increased from 482 to 484 m, which was followed by a much slower and still linear decrease as lake levels continued to rise (Figure 6). Thus, this study shows that kapenta-fishing effort had strong and significant negative impact on kapenta catches, with increasing maximum temperatures and lake levels also associated with significant decrease in catches.

Table 3: Results of the GAM test for the relationship of kapenta CPUE to fishing effort, lake level, rainfall, and temperature (maximum and minimum).

Anova for Parametric Effects					
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
s(Effort)	1	0.45516	0.45516	256.8122	**2.552e-14**
s(Max_temp)	1	0.00216	0.00216	1.2168	0.2809328
s(Min_temp)	1	0.00149	0.00149	0.8398	0.3685821
s(Lake_level)	1	0.02758	0.02758	15.5607	**0.0006059**
s(Rainfall)	1	0.00009	0.00009	0.0529	0.8199577
Residuals	24	0.04254	0.00177		

Anova for Nonparametric Effects			
	Npar Df	Npar F	Pr(F)

(Intercept)			
s(Effort)	3	6.1623	**0.00294**
s(Max_temp)	3	11.0805	**9.304e-05**
s(Min_temp)	3	0.5170	0.67457
s(Lake_level)	3	1.0227	0.40006
s(Rainfall)	3	1.9872	0.14278

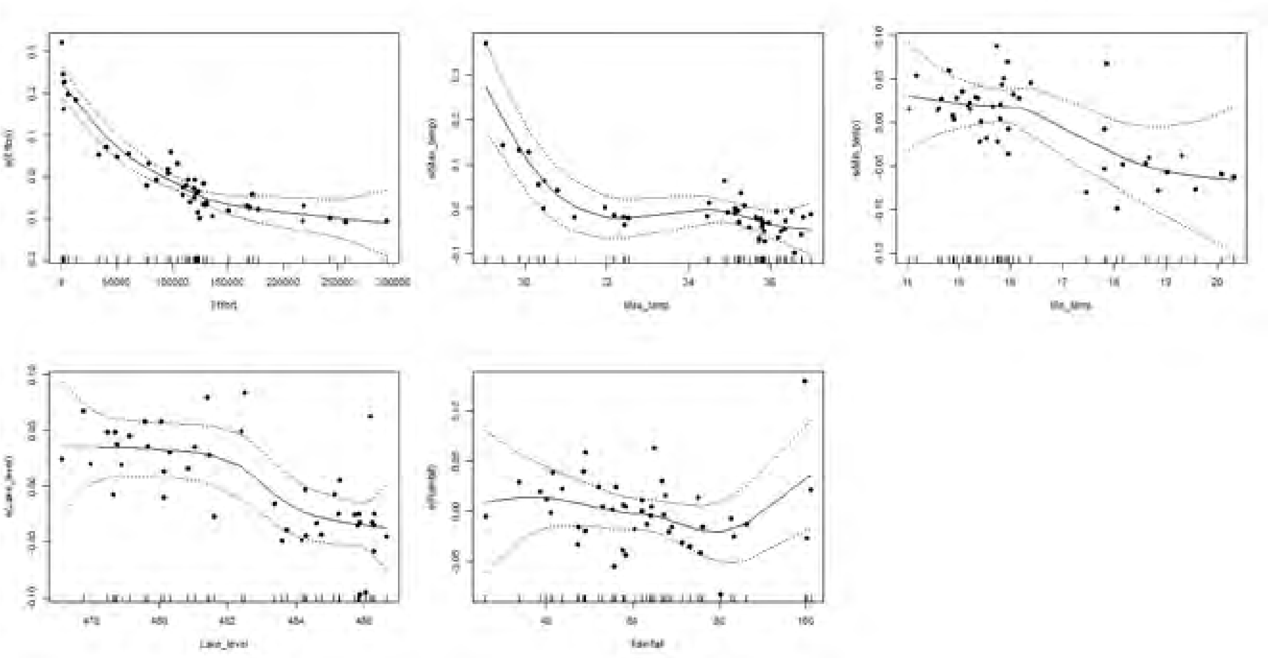


Figure 6: Graphical presentation of the relationship of kapenta CPUE with fishing effort, lake level, rainfall and temperature (minimum and maximum).

Impact of rainfall on kapenta yield

Our analysis shows that kapenta catches in Lake Kariba drastically decreased between 1974 and 2018, with fishers harvesting about 0.066 tonnes/night from 2015 to 2018, compared to 0.517 tonnes/night between 1974 and 1979. We show that there has been no significant change in rainfall trend from 1964 to 2018, and concurrently no significant relationship between rainfall and kapenta CPUE. Although we looked at rainfall data from one meteorological station, our results on rainfall trend are supported by findings by Muchuru *et al*. (2016) and Kampata, Parida and Moalafhi (2008). Muchuru *et al*. (2016) analysed rainfall data from 13 stations in Zimbabwe across the Lake Kariba catchment for the period 1970 to 2010, and found that there were no significant shifts in annual and seasonal rainfall. Similarly, Kampata *et al*. (2008) who analysed rainfall data from five stations in the headstream regions of the Zambezi River basin in Zambia, found no significant trend in rainfall.

Impact of water level fluctuations on kapenta yield

Water level fluctuations are an important factor in lakes as they affect many ecological processes, including productivity and biodiversity (Gafny, Gasith, Goren, 1992; Gafny & Gasith, 1999; Wantzen *et al*., 2002). In lakes, fluctuations occur naturally through seasonal or long-term imbalance between water entering (by inflow, precipitation, runoff, and groundwater) and leaving (by evaporation and outflow). Additionally, for man-made lakes such as Lake Kariba that are used for hydroelectric power-generation, a substantial amount of water is lost through turbines used for power-generation. In lakes and reservoirs that are intimately associated with rivers, production is dominated by changes in the hydrological regime (Talling, 1986; Welcome *et al*., 2006), and nutrient supplies from affluent rivers and the flooded marginal areas are critical in stimulating fish-production (Kolding and van Zwieten, 2012; Bayley, 1991).

The current study showed that following a period of high-water levels from 1964 to 1982, Lake Kariba experienced a 16-year period from 1983 to 1998, during which it was characterised by relatively low water levels. Since then, water levels as well as the magnitude of water level fluctuations have increased. Theoretically, the resultant increase in inundated area due to the increased water levels, and the greater fluctuations from 1999 to 2018, resulting in what Bayley (1991) called the 'flood pulse advantage', should have been associated with increase in CPUE for kapenta. Our analysis though, showed that this was not the case as increase in lake level was negative and significantly related to the CPUE.
Ndebele-Murisa *et al*. (2011) reported a significant negative relationship for water level with kapenta catches (not with CPUE), but a non-significant relation between water level and kapenta CPUE. An earlier study by Karenge and Kolding (1995) showed that kapenta CPUE was not correlated with absolute water levels but showed high correlation with different time-lagged indices of water level, whilst Chifamba (2000) reported positive correlation for Kapenta CPUE with water levels. The discrepancy between our study results and those by Karenge and Kolding (1995) and Chifamba (2000) are largely due to differences in the time periods covered by the studies. Our study explored a much longer period than the other studies, comprising the period before 1980 when water levels were high and magnitude of fluctuations relatively low, to the period 1983 to 1998 when water levels were low, and from 1999 to 2018 when levels were relatively high. As has been already noted, kapenta CPUE has generally undergone a decrease since the commencement of commercial fishing in 1974. As kapenta CPUE decreased when lake levels were high from 1974 to 1982 and continued to decline during the drought years (1983 – 1984, 1990, 1992 and 1995) when levels were low, it is therefore not surprising that water level was not significantly associated with kapenta CPUE. Although there was an increase in mean water level from 1999 to 2018, the kapenta CPUE continued to decrease. Therefore, our study found an overall negative and significant relationship between water level and kapenta CPUE.

Impact of temperature on kapenta yield

Our analysis showed that both maximum and minimum air temperatures changed significantly between 1964 and 2018, with maximum air temperature increasing by about 0.117 °C/year, which was an increase of about 6.4 °C, whilst minimum air temperature decreased by 0.051°C/year, a decrease on average of approximately 2.8°C. The growth of fish is strongly dependent on water temperature. In an environment with abundant food, fish growth rate generally tends to increase with increase in temperature, up to an optimal temperature, after which it rapidly decreases (Jobling, 1997). In natural environments, food is not always abundant such that growth decreases with increasing temperature due to increased energetic demands from higher metabolic rate at higher temperatures. Temperature also affects virtually all aspects of reproduction in fish including gametogenesis and gamete maturation, ovulation/spermiation, spawning and subsequent early development (Van Der Kraak and Pankhurst, 1997), thereby affecting recruitment success and yield.

Our analysis showed that maximum air temperature relationship to kapenta CPUE was significant, negative and non-linear, whilst the relationship with minimum air temperature was insignificant. Generally, as maximum temperature increased there was a quadratic decrease in kapenta CPUE. Chifamba (2000) also suggested that maximum air temperature defined by a quadratic function is the best predictor of kapenta CPUE when compared to rainfall, river inflow and the water level, whilst according Ndebele-Murisa *et al*. (2011) maximum temperature together with nutrients are the primary determinants of kapenta production.

Impact of fishing pressure on kapenta yield

Over the 45-year period from 1974 to 2018, fishing effort on kapenta on Lake Kariba increased at a rate of 2811.3 nights of fishing per year. The most recent studies that have been done to determine the trend in kapenta catches have tended to ignore or discount the effect of fishing effort/pressure, or if they did (e.g., Ndebele-Murisa *et al*., 2011) they tended to only consider fishing effort from either Zambia or Zimbabwe, but not both. In this study the annual fishing effort considered the two countries. Generally, fishing effort was relatively low and steady from 1974 to 1978, but steadily rose thereafter, and the increase in effort was significantly and negatively associated with kapenta CPUE.

CONCLUSION

The results of this study suggest that maximum air temperature, lake level and fishing effort had significant impact on kapenta catches in Lake Kariba. Generally, increase in maximum air temperatures were associated with decrease in kapenta catch per unit effort. This is in agreement with assertion by Magadza (2010) and Ndebele-Murisa *et al*., (2011a, b) that climate-change, in particular increase in temperature, has had a negative impact on kapenta catches in Lake Kariba. High water levels and greater water level fluctuations have not been associated with greater kapenta CPUE as would have been expected with the 'flood pulse advantage' (see Bayle, 1991). The continual decrease in kapenta CPUE since commercial fishing began, and even before climate warming was an issue of concern, suggests that fishing effort (pressure), which has grown tremendously has also had significant negative impact on kapenta yields in Lake Kariba. Unlike Marshall (2012) who asserts that the impact of fishing is the only factor that can explain the decline in kapenta CPUE, we conclude that increased fishing effort/pressure has been a major factor, but indeed warming of the climate has worsened the decline in kapenta catches.

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CHAPTER **10**

CHALLENGES OF CLIMATE-CHANGE MITIGATION PROJECTS AND MEETING LIVELIHOODS DEMANDS OF LOCAL COMMUNITIES: A CASE OF THE KARIBA REDD+ PROJECT IN HURUNGWE DISTRICT, Zimbabwe

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Source: https://www.offsetalliance.co/kariba

ABSTRACT

This chapter looks at local concerns around the privately run Kariba Carbon Redd+ Project (KCRP) in Hurungwe District, Zimbabwe. Its main objective is to evaluate the effects of climate change mitigation strategies through community-based forest conservation. Under the project, local communities are encouraged to preserve forests in return for support for sustainable livelihood initiatives aimed at poverty-alleviation. The chapter seeks to unveil the community's perceptions on the project and how it has impacted on existing livelihoods. To do this, interviews, seasonal calendar and focus group discussions were held with participants and project architects. Secondary sources, including online documents, were also used. Results show five concerns that, from the community's view, may threaten the project's future. These include lack of transparency and consultation; unclear distribution of funds; lack of benefits that accrue directly to the unit of consumption (household); unacceptable alternative livelihood activities; and failure to fulfil some promises. The chapter concludes that these concerns, particularly the failure to meet individual household needs, are synonymous with top-down initiatives crafted in foreign environments, with no regard for local needs. If not addressed, they pose a threat to the project's goal of mitigating climate change as the community is set to resist/sabotage the afforestation drive. The chapter recommends that, in order to succeed, projects designed to mitigate climate change must be locally grown so that they are sensitive to the prevailing local livelihood activities. Future projects must also be assessed in line with their effectiveness, equity and efficiency before implementation, as envisaged in the 3E framework.

Keywords; *Climate-change; Mitigation; Livelihoods; Community-based forest management*

INTRODUCTION

This chapter investigates the perceptions of the community in Chundu Ward, Hurungwe, on the performance of the Kariba Carbon Redd+ Project (KCRP), a climate change mitigation project, in improving the livelihoods and well-being of the community. It concentrates on the effects of the project's thrust of mitigating climate change through community-based forest conservation. In particular, the chapter seeks to establish, from a local perspective, if the project has been able to improve local livelihoods, to what extent and with what challenges.

The discourse on the impact of global climate change and variability has been at the top of the research and policy agenda, but more so in developing countries where the impact is expected to be more devastating due to low adaptive capacity (Brown *et al*., 2012). Zimbabwe, a generally semi-arid region, already has very limited and unreliable rainfall and ever-changing temperature patterns (Phiri *et al*., 2019). With climate change, it is indicated that these weather patterns have intensified, with decreases in the frequency and intensity of heavy rainfall events, increases in the proportion of low rainfall years, and increases in the frequency and intensity of mid-season dry-spells (Unganai, 2009). Climate change and variability have also resulted in drying up of large trees at an alarming rate partly due to a reduction in soil moisture caused by persistent and extended droughts. These conditions have been further exacerbated by extreme weather events, such as tropical cyclones (Dunne, 2019).

Climate-related changes have been projected to have far reaching socio-economic and environmental consequences for vulnerable communities in the country, most of who reside in rural areas and rely on rain-fed agriculture (Nyahunda & Tirivangasi, 2019). For instance, in addition to the general vulnerability of communal agriculture, it is projected that suitable areas for maize, the major staple food, and surface water resources will decrease significantly by 2080 (Brown *et al*., 2012).

On an international scale, the United Nations Framework Convention on Climate Change (UNFCCC), of which Zimbabwe is a signatory, was set up and ratified in 1994 to coordinate a global response strategy. The UNFCCC requires signatories to put in place measures to reduce atmospheric concentrations of greenhouse gases in order to minimise anthropogenic interference with the earth's climatic system (UNFCC, 2013). Since then, there have been several other international protocols, all designed to deal with reducing the production of greenhouse gasses. In order to fulfil its commitment and obligation to global protocols, the Government of Zimbabwe adopted a Climate Policy in 2016 and one of its primary goals is to accelerate mitigation measures by adopting low carbon development pathways (Zimbabwe Climate Policy, 2016).

The Kariba Carbon REDD+ Project, a privately-run community-based project responds to this call to mitigate climate change through low carbon pathways. The project is rooted in the United Nations programme, Reduced Emissions from Deforestation and Degradation (REDD) Programme, established in 2008, as part of a worldwide goal to reduce the production of greenhouse gases, which cause climate change (Angelsen, 2008). Its offshoot, the REDD+ project, is essentially a carbon-based compensation mechanism targeting tropical forests for reducing carbon emissions and/or enhancing carbon sinks (UNFCC, 2013). It operates on the premise that for every tonne of avoided greenhouse emissions achieved by reducing deforestation and degradation, the project receives credits that can be sold in offset schemes on the international market to companies and institutions with a voluntary or compliance carbon reduction strategy (Angelsen & Kanounnikof, 2008).

The KCRP is, therefore, rooted in the REDD and REDD+ projects. To date, the project has been implemented in Hurungwe, Binga, Mbire and Nyaminyami districts where communities in selected wards are to preserve surrounding forests. In return, the project promises funding for community development initiatives aimed at poverty alleviation, such as sustainable honey production with links to markets, conservation agriculture, ecotourism and low-emission brick production methods, all of which are meant to create jobs and facilitate sustainable incomes across the districts.

The case for this chapter is built around the project activities in Hurungwe. Questions are raised as to whether, from the community's perspective, the project has managed to improve local livelihoods through its afforestation activities, to what extent and with what challenges. The chapter starts by presenting the background to the KCRP, followed by a brief description of the study area and an outline of the data collection methods used. The chapter then presents the results of the study, followed by a discussion, recommendations and lastly, a conclusion.

KARIBA REDD+ PROJECT: THE BACKGROUND

The Kariba REDD+ project was initiated in 2011 by two private companies, Carbon Green Investments Africa and South Pole Carbon Asset Management (Dzingirai & Mangwanya, 2015). The local implementing partner, Carbon Green Investments Africa based in Harare, is run by largely white staff, most of whom have backgrounds in local safari-hunting and large-scale commercial farming, backgrounds which give them an advantage in managing the project (Dzingirai & Mangwanya, 2015). A starting capital of about US$ 500 000.00 was provided by a white Zimbabwean entrepreneur, who also has interests in the country's environmental issues. The other partners include Environment Africa, a non–governmental organisation with interests in the sustainable use of natural resources. The Hurungwe Rural District Council (HRDC) is also another partner in the project, together with the councils of other participating districts, and its role is mainly to provide land and control the local communities from engaging in unsustainable environmental practices (ibid). All these partners converge on one belief: that local communities are not using natural resources sustainably leading to deforestation, land and forest degradation, hence the need to come up with private sector-led initiatives to manage the environment. It is therefore on this basis that the community was involved as a partner in the project.

The Kariba REDD+ Project, seeks to protect almost 785,000 hectares of forests and wildlife in Binga, Mbire, Nyaminyami and Hurungwe. The project area covers four national parks, namely, Chizarira, Matusadona and Mana Pool and Zambia's Lower Zambezi National Park and eight safari reserves including Chevore and Sapi, creating a giant biodiversity corridor that protects an expansive forest and numerous vulnerable and endangered species. It is programmed to run for 30 years, starting from October 2011 to September 2041 (Silber, 2011). The project is inspired by the observation that deforestation and forest degradation account for about 12-29% of global greenhouse emissions, a development which may exacerbate climate change if not addressed

(Silber, 2011). It is this impending environmental disaster that this project seeks to address.

The KCRP operates on the premise that for every tonne of avoided greenhouse emissions achieved by reducing deforestation and degradation, it receives credits that can be sold in offset schemes on the international market to companies and institutions with a voluntary or compliance carbon reduction strategy. Basing on this, the project aims to prevent the emissions of 52 million tonnes of carbon dioxide into the atmosphere over a period of 30 years (Angelsen & Kanounnikof, 2008). This also amounts to an equal number of carbon credits to be created by the project for sell in the offset schemes. To achieve this, KCRP has engaged communities in the four districts to preserve forests in order to raise the required carbon credits. Ultimately, this also makes it a community-based project. The proceeds from the offset schemes are to be shared among the partners with 20% of the net profit being reinvested into the general activities, promoting and guaranteeing the project's sustainability with a promise that since it is on communal lands, the people living within those areas will have 'their lives enriched by the project' (Silber, 2011).

The promised benefits to the community are twofold. Firstly, the project contributes to the preservation of its surrounding environment in a way that mitigates climate change, while also protecting the community from the devastating effects of this phenomenon. Secondly, the project promises to tackle the issue of poverty, purportedly promoting the independence and well-being of the participating communities (Brown, Seymour & Peskett, 2008). In return, the community is expected to treat surrounding forests as valuable assets, not only for the mitigation of climate change effects but also as an opportunity for income-generation. The communities then get wide-reaching benefits in the form of financial support for various projects such as sustainable honey production with links to markets, conservation agriculture, ecotourism and low-emission brick-making production methods, all of which are meant to create jobs and facilitate sustainable incomes (Angelsen & Kanounnikof, 2008). For example, project documents show a harvest of 2,974kg of honey from the 84 beneficiaries of the bee-keeping projects with a total income of $5, 485.00 between February 2014 and June 2016 (Silber, 2011). The projects are specially chosen and designed to deter agricultural encroachment, burning of forests and wood-poaching. The benefits also include improved health amenities, infrastructure (including new roads and boreholes), and school subsidies offered to the poorest quartile of the population. It is these envisaged community benefits that this chapter concerns itself with, particularly the extent to which the project in Hurungwe District has succeeded in its mandate to alleviate poverty and ensure sustainable use of natural resources. The next section presents the study area.

The Study Area: Hurungwe District

Hurungwe District lies on the margins of the northern part of Zimbabwe, about 136km from the Zambian border. In 2012, it had a population of about 342,675 (Zimstat, 2012). The district is characterised by large reserves of forests and woodlands, totalling about 13,140 hectares. It has significant numbers of wildlife resident in the communal and protected areas that border the district, thus making it ideal for conservation projects. The protected areas include Sapi Safari Area to the northeast, Chewore Safari Area to the east and Mana Pools National Park to the north, all giving a total coverage of just over 6,000 square kilometres (Mangwanya & Dzingirai, 2015). The remaining forest land that lies between the protected areas and human settlements is what has been targeted for the carbon project. The study concentrates on KCRP activities in Chundu Ward, an area bordered by national parks and safari areas (Bird & Metcalfe, 1996).

Chundu Ward is inhabited by different social groups, all pursuing different interests. Besides the indigenous communities, there are sport hunters and safari operators, largely white and most of the victims of the late 1990s fast track land reform programme. They see the area as one of the last greatest wildernesses in Africa and are keen to use that to their advantage as they have heavily invested in lucrative tourist and hunting enterprises stretching from Hurungwe to the Zambezi Valley (Dzingirai & Mangwanya, 2015).

The indigenous population consists of people from different backgrounds, most of whom ended up in the Ward through some form of 'structural violence' (Farmer, 2010), having been moved into the area as a result of a series of developments that were crafted, ostensibly, to benefit them although in reality, they disenfranchised them (Mangwanya & Dzingirai, in press). These developments, which date as far back as the 1930s, include land apportionment and redistribution, construction of the Kariba Dam, creation of Karoi Farms and the Communal Areas Management Programme for Indigenous Resources (CAMPFIRE). In all developments, the local communities were promised jobs and land that would give them modern lifestyles but were instead displaced into Chundu Ward, which at that time was a wilderness infested with wildlife and tsetse flies.

The advent of CAMPFIRE, for example, a programme somewhat similar to KCRP, the community was promised wide ranging benefits including household dividends and community projects, such as and clinics (Balint, 2009). But to make way for this programme, the local authority re-zoned the district, creating buffer zones where, ironically, people were already settled. Those settled to the east of the buffer zone were, henceforth, defined as 'squatters' and instructed to vacate, something which they have always resisted (Bird & Metcalfe,1996). Refusal to vacate the newly designated buffer areas prompted the HRDC to issue eviction orders to these newly created 'squatters' who have in their defence sought reprieve from the courts through human rights lawyers (Dzingirai & Mangwanya, 2015). Besides displacing people, the programme has been criticised for not being responsive to local concerns and livelihood strategies, protecting wildlife instead of people, elite capture and abuse of revenues by the HRDC (Balint, 2009). The KCRP is, therefore, being introduced against this background, where the community has mistrust towards any development project.

STUDY SITE SELECTION AND SAMPLING METHODS

A multi-stage sampling technique was used to select the study site as well as respondents. Purposive sampling was used to select Hurungwe District and Chundu Ward. The KCRP is present in Nyaminyami, Binga, Mbire and Hurungwe Districts. Hurungwe was selected because of its diverse population, development history and wide natural resource base on which most livelihoods are based. Within Hurungwe, the project is present in Wards 7, 8 and 9. Chundu Ward (Ward 7) was selected because of its proximity to the protected areas, where the land targeted for forest conservation lies. Within the Ward, random sampling was used to select seven villages from 56 villages that make up Chundu Ward. Each village has about 30-50 households. Within the villages, random sampling was also used to identify interview participants. Key informants and focus group participants were identified with the help of the Chief.

DATA SOURCES AND COLLECTION METHODS

Qualitative methods, including interviews, focus group discussions, a seasonal calendar and secondary sources were used to collect data for the chapter. In all these methods, efforts were made to engage the community, giving its members a chance to participate actively in the generation of knowledge that pertains to them. A total of 70 interviews (ten in each village) were conducted. Among those interviewed were members participating in various KCRP projects, such as gardening and beekeeping. Efforts were made to include participants from all social groups. The interviews were used to collect data on the activities of the project and local perceptions on the success and problems associated with it. Key informants, including three village heads, chief, youth leader and the local KCRP project coordinator were also interviewed to get their views and stance on the project and its effects on local livelihoods.

The study also used a seasonal calendar, drawn by participants from across different social groups in the community and with the aim of depicting which livelihood activities were carried out by who and at which time of the year. Furthermore, two focus group discussions were carried out at the start and end of the fieldwork. Twelve participants, drawn from all the participating villages and comprising all social groups, took part in each discussion. Issues discussed included the participants' views on deforestation in general, its link to tobacco cropping and how it can be reduced, as well their take on the project's activities vis-à-vis their livelihoods. The chapter also gained invaluable knowledge from project documents, most of which are available online.

Data Analysis Methods

Data was analysed using the content analysis technique which involved reading and rereading transcribed data from interviews and focus groups, paying particular attention to meanings (Vaismoradi, Turunen & Bondas, 2012).

RESULTS AND DISCUSSION

This chapter investigates the perceptions of the community in Chundu Ward, Hurungwe on the performance of the KCRP, a climate mitigation project, in improving the livelihoods and well-being of the community. In particular, the chapter seeks to establish, from a local perspective, if the project has been able to improve local livelihoods, to what extent and with what challenges.

From the data obtained in this study, the community indicated that it is yet to see any tangible benefits from the project since its inception in 2011. The community felt that the project has not been able to deliver its promises. They indicated that when the project was being advertised to the community, it had flashy pictures, full of the promise of a good life. The pre-project pictures depicted a poor rural environment with malnourished children on barefoot, attending school in open classrooms. This was sharply contrasted with pictures synonymous with famous religious pamphlets, showing large green pastures with flowing rivers, a wide variety of animals and fruit trees and happy, well-clothed and well-nourished families. The big question, therefore, is what has derailed this promised 'heaven on earth' scenario. This chapter highlights five areas that have the potential to derail the project from achieving its objectives.

Lack of Grassroots Consultation Alienated users from Participation

The study established that the lack of grassroots participation during project planning and implementation reduced its prospects of achieving intended results. From the onset, the project used a blueprint thinking and influence that denigrated the innovative capacity of the indigenous people. For instance, the project has not been able to adequately consult and educate the locals on its objectives in a language that they understand. Even with several workshops, the locals could not understand what 'carbon' is and what it has to do with their daily lives. As reported by Dzingirai and Mangwanya (2015, p.158), all that some interviewees could say about the project was that it was 'about clouds'; 'about smoke in the air', or 'about our trees.'

Lack of understanding of project objectives has also been recorded in Nyaminyami, where one official from the district office professed that although they had signed a contract to engage in the KCRP, they still did not fully understand the project issues and processes and attributed this to lack of a national mechanism to address capacity gaps (Newsday, 10 June 2015). This lack of knowledge among the communities has also been acknowledged by the project officers in an interview with a local newspaper,

> It has been difficult to explain but I hope with the awareness campaigns we are doing, communities will begin to understand what we are talking about (The Herald 27 October 2014)

So, from the onset, the communities and their leaders did not fully understand what they were getting involved in and why. This has also created legitimacy issues around the project's designation as community-based. From the interviews, there was no adequate consultation at the community level before the project was introduced. As indicated by one village head,

> These people just came here without our permission. We were just called by the chief and told that we are supposed to participate and that it is good for us. Our opinions were not sought (Interview Mangwaira Village, 22 March 2014).

Besides the lack of consultation and providing adequate knowledge on the project, there have also been concerns that the community is not involved in decision making. These sentiments were raised by the local councillor for Chundu Ward who argued that the project was not doing enough to empower the community while at the same time making 'unilateral decisions' regarding its operations. It seems, therefore, that the grassroots communities are in the dark about the objectives and operations of the project, something which is likely to affect their participation.

Lack of Tangible Incentives has Discouraged Local Participation

Another problem with the project is that it has failed to separate the unit of management from the unit of appropriation, resulting in poor incentives for the local communities to effectively participate in the management of the forested land. In trying to divert from the experience of CAMPFIRE, where proceeds due to the community were distributed through the HRDC, this project promised to ensure that proceeds meant for the community will not be misappropriated by the HRDC. In its documents, the project states that,

> A significant (20%) of the net profit share of the project's carbon income will be invested into general activities promoting and guaranteeing the sustainability of the project. The project is being undertaken on communal lands and as such, it is imperative the people within these communities have their lives enriched by the project (http://www.carbongreenafrica.net/about-us-.html)

However, this has remained a pipe dream simply because, legally, the HRDC is responsible for development projects within the district and hence all income that is realised through the project. Furthermore, the land on which the project is run is owned by the state and administered by the HRDC, with the community only having usufruct rights. This means that the community does not have much say on such projects and the funds generated from them.

From the interviews, it was clear that the proceeds from the project have not been flowing directly from its coffers to the community. As indicated by a local village leader,

> We just hear that we are supposed to get money from keeping forests. But to be honest, no one has seen that money. The money is for the Council, not us. They are using us to get donor funds (Interview, Kapoko Village 21 February 2014)

From the community's perspective, the benefits from the project have been accruing to the various organisations facilitating the project, with the community benefitting only on paper. As indicated by one community leader during a focus group discussion,

> We have not seen the benefits of the project here at the local level. We only see the other so-called partners driving big cars. They only involve us so that they can tell their big donors that they are doing it for us, but we have seen nothing from it (Focus Group Discussion, Chitindiva Primary School, 20 March 2014)

Similar experiences have also been recorded in the other rural district councils engaged in the project. A local newspaper captured the following sentiments by a local Ward councillor in Binga District,

> There is an outcry in Binga…. We have not seen anything really tangible, financially or otherwise ….We do not understand what REDD+ is all about. My officers told me that Carbon Green Africa is there to take pictures (The Herald 27 October 2014).

The government, through the Ministry of Environment, Water and Climate Change, has also accused the Carbon Green company, of short-changing the communities through RDCs and reaping millions of dollars from this 'green gold' while the actual participants at the grassroots level are suffering. As indicated by a senior official from the Ministry at an international conference,

> RDCs can enter into agreements with private players ill-informed of the deals involved and this leaves them vulnerable to investors…….making false promises while reaping millions (Newsday, 10 June 2015)

However, in its defence, the HRDC has also professed ignorance regarding how much has been generated by the project to date. As indicated by one HRDC official

> I am telling you, we are in the dark about what these guys (*i.e project leaders*) are doing. These people are not straightforward at all (Hurungwe Council Officer, 10 November 2013 (adapted from Dzingirai & Mangwanya, 2015)

In its defence, KCRP's stance is that the project has been affected by a low uptake of carbon credits internationally as indicated by one senior official of Carbon Green Africa,

> The major challenge is the slow uptake of the credits on the voluntary market….the rural communities are asking for more yet financial resources cannot meet demand (Reuters, 29 March 2017)

Study findings show that most buyers are international companies while local companies have shown little or no interest in the project because there is no law compelling them to buy carbon credits. Given that there are over 400 REDD+ projects worldwide, there is high competition for the funds and Zimbabwe's complex political situation makes it difficult to attract buyers.

Project officials have also argued that for the funds received so far, distribution to RDCs is proportional to each council's shareholding in the project or is based on the amount of forested land contributing to the project. Thus, according to project documents, Hurungwe has the least shares, 17%, when compared with Mbire, Nyaminyami and Binga which hold 34, 29, and 20 percent, respectively. But even, the little that the project has disbursed to the HRDC is still to be felt by the communities at the grassroots level. So as far as the community is concerned, the project lacks transparency in terms of the distribution of outputs and so if the individual players at the grassroots level are not seeing the benefits of the project, compliance to its objectives cannot be expected.

Emphasis on Community Welfare Disparage

A further fallacy with the project is that it is based on a principle that improving societal welfare will generate incentives within communities to sustainably manage the forested lands. As a result, there is no emphasis on compensating individual households that stand to lose from reduced exploitation of the forest resources. The project acknowledges that so far, priority has been on funding community projects and not individual incentives as indicated by one official,

> The money the Mashonaland West communities have received so far - initially from private investment until the Kariba REDD+ carbon credits were issued on the market in 2011 – has been spent on planting new trees, training farmers in conservation agriculture and community projects (Reuters, 29 March 2017).

The fact that there is no benefit specifically targeted at the individual households that comply with project requirements acts as a deterrent to those that want to support it. Ultimately, this creates a conflict between those who comply with the demands of the project and those who do not. More often than not, people choose not to comply simply because they still enjoy the proceeds from the project which are usually communal. The situation is worsened by the fact that firewood remains a major source of energy and despite the promise by the project to provide some wood efficient cookstoves that can consume up to 60% less wood, these have not been forthcoming. As indicated by one interviewee,

> People are generally reluctant to comply because everyone receives the same benefits, regardless of whether one complies or not. So you find that some people are cutting trees while others do not, but at the end of the day we all get the same benefits. So why should I not also cut trees if I need firewood (Interview, Mayamba Village, 16 March 2014).
> Says another,

> When schools open, the headmaster wants to see receipts that school fees have been paid. Those who are growing tobacco are able to pay fees. And yet someone who preserved their land and forest for the project fails to pay fees. So what do you think people will do under such circumstances? (Focus Group Discussion, Chitindiva Primary School, 15 May 2015)

From the community's perspective, compliance can be achieved if the project has a clearly tangible and concrete policy on the distribution of benefits such that dividends accrue solely to those households that comply with the project's requirements. Furthermore, the rewards must provide an incentive to individuals/households to participate in the project.

Focus Purely on Forest Management Denigrates Local livelihoods

The proposed forest management system has failed to take into consideration the community livelihood activities practised over time. The prescriptions contained in project documents disregard local livelihood strategies, thus making it difficult for achievement of project success and sustainability.

Main livelihood activities pursued in the area are land and nature-based and these include mainly, but not exclusively, crop production (including gardening), livestock rearing, foraging, hunting and gold panning. From the community viewpoint, each of these has, in a way, been affected, or is at risk of being affected, by the project.

For crop production, involving mainly maize and tobacco, the farmers indicated that the project has affected their yields because they cannot expand their fields since deforestation is discouraged by the project. But it is largely the tobacco growers who are crying foul over the project despite the fact that this is the crop that has been fingered as the major cause of deforestation and land degradation, a situation which has seemingly caused the KCRP to step in. Two problems associated with tobacco farming have been raised. Firstly, the crop is a high-income earner where farmers have a chance of earning the elusive United States dollar. Because of this, farmers aim to maximise their profits from the crop and to do this they expand their fields as far as they can. In the process, they clear massive tracts of whatever land they may deem unused so that they extend their tobacco fields. The situation is worse at the outskirts of the Ward where new settlers have access to large tracts of land stretching into protected zones and safari areas. As noted by one villager, tobacco growing is one of the major causes of land degradation in the area,

> *"Tobacco is the reason why this place is a desert now. People from all over are coming here to look for land to grow the crop and they are given a lot of land by the village heads in return for some tokens (Interview, Mayamba Village, 21 February 2014) "*

Secondly, most farmers grow flue-cured tobacco, this being the type that requires a lot of heat for curing. As most farmers want to minimise investments into the crop, they avoid using coal, the source of energy recommended by the Environmental Management Agency (EMA). Even the local chief has been active in calling upon his people to desist from cutting trees.

> *"We are encouraging tobacco farmers to have their own woodlots to cure tobacco. If a farmer does not have such a woodlot, we advise them not to grow tobacco (Reuters, 29 March 2017). "*

But farmers ignore this call. Instead, they look to the nearby forests for firewood to cue the crop. As indicated by one farmer during a focus group discussion,

> *"EMA says we should use coal for curing tobacco. But who has that kind of money to buy the coal? (Focus Group Discussion, Chitindiva Primary School, 20 March 2014) "*

There are also those migrant households that have settled at the periphery of the Ward, which is still heavily forested. For these, there is absolutely no need to buy coal when they have forests around them. As one recent migrant at the frontier put it,

> *"We moved here because there was plenty of land and trees for tobacco. Why then should we pay a lot of money for coal when God gave us all these forests? How then do we make profits? (Interview, Mahwau Village, 7 December 2013) "*

The fact that tobacco farming has been the biggest cause of land and forest degradation is well acknowledged. For instance, Chief Chundu recently indicated that he was 'engaging various agricultural players to pull away his subjects from tobacco farming' (Reuters, 29 March 2017), something which he has failed to do to date. The KCRP has encouraged other forms of farming like conservation farming. But still, this has faced resistance, as indicated by one farmer during a group discussion,

> *"The project is encouraging conservation farming for soya beans and maize but is silent on tobacco. They say it destroys trees. Who cares about trees when we are starving? (Focus Group Discussion, Chitindiva Primary School, 20 March 2014) "*

Livestock production is yet another livelihood activity which the community feels is threatened by the project. The activity is quite recent because it was prohibited for many years as a tsetse control measure. Now that the area has been almost cleared of the fly, households are keen to invest in livestock. However, because of the continued threat from trypanosomiasis, it has to be done in a way that protects cattle from the disease. One way is to ensure that the area is clear of thick forests and tall grass that provides habitat to the fly. As a result, villagers engage in slash and burn tactics to clear forests in order to destroy tsetse habitat and protect themselves and their livestock from the fly. However, this practice is in direct contrast to the project's main objective of forest conservation, thereby creating a conflict of interest between project objectives and the livelihood activity. As indicated by one villager,

> *"This project is bringing tsetse here. We have worked very hard to clear forests so that tsetse goes away and we can keep cattle. Now we are being told to protect forests again. How will our cattle survive because this will bring back tsetse (Interview, Kabidza Village, 7 February 2014) "*

From the community's perspective, the project is considered a threat to this livelihood activity and as indicated below, they will not stand by and watch this happen,

> *"We have waited so many years for this area to be cleared of thick forests so that we can also have cattle and be respected as men (cattle is a symbol of wealth). Now they want to bring back the forests and attract tsetse again. We will not stand by and let them destroy our investments and heritage for our children. (Interview, Kabidza Village, 7 February 2014). "*

There were also concerns from those settled at the frontier who felt that the project had robbed them of their grazing spots,

> *"We had abundant grazing areas here. Now they tell us that our cattle are not allowed into these forests. Where are they supposed to graze? We are now being treated as criminals yet all we want is food for our livestock (Focus Group Discussion, Chitindiva Primary School, 15 May 2015) "*

Lastly, the villagers also believe that KCRP threatens their hunting activities. This is because the project also plans to introduce wildlife utilization initiatives, targeting elephants, buffaloes and lions. Like, CAMPFIRE, the project promises to give local people an opportunity to own wildlife and enjoy the revenue from it. It promises to relieve wildlife from poaching through increased monitoring, patrols and number of man days spent on patrolling per year.

In return, the community has to desist from poaching. Yet hunting, although illegal, remains an important contributor to the household economy as it provides a main source of protein, with the excess being sold off on the market. The activity takes place in thick and forested places which include the surrounding protected areas. And yet, these are the areas targeted by the project for both forest and wildlife utilisation. But as history has shown, the communities never get real ownership of wildlife and the monetary proceeds therefrom (Hutton, Adams & Murombedzi, 2005). As a result, they disregard the objectives of the project and proceed with poaching activities. This is the scenario prevailing in Chundu Ward as detailed by one hunter who emphasised anonymity,

> *"We are expected to preserve wildlife and not kill it. But we need meat. So we have no choice but to go into the forest and look for meat. Otherwise, we starve. The other thing is that the animals they want to protect can destroy our livestock and crops if they stray into the villages. So we will not stand by and watch as wildlife destroy our livelihoods. (Interview, Mayamba Village, 7 March 2014) "*

As part of a hunting tactic, the hunters burn vegetation so that the dogs can easily chase their prey. This is totally against the project principles but the hunters are adamant that they will continue because they have to eat. As put by one of them,

> *"We have to eat. We can't preserve trees and animals at our expense (Interview, Mayamba Village, 7 March 2014) "*

In essence, hunters view the project as a threat to their activities, and so are unlikely to adhere to the project's rules and regulations. It is clear from these three examples that, from the community's perspective, the project is a deterrent to existing local livelihood activities and as such, adherence to its requirements is unlikely.

Unfulfilled Promises Discouraging Community Participation

Failure to invest in trust-building, which is a key driver of the social contract between implementers and the target project beneficiaries has resulted in lack of support for the project by the locals as they deem project implementers to be insincere. This insincerity has caused the community not to trust project officials and hence, they have continued with practices that contradict sustainable management of forests. For instance, the project encourages the adoption of conservation farming, a system that discourages tillage to assure soil protection while reducing land degradation and increasing water and nutrient use efficiency (Giller *et al*., 2015). This means that the community has to desist from cutting trees and clearing vegetation for agricultural purposes. To promote this, the KCRP promised to provide seeds and fertilizer to the farmers. However, the villagers indicated that only a few people had received the inputs as these were later withdrawn without notice. This was confirmed by one official who indicated that,

> *"At the council meeting, it was agreed that we should use the resources available to train more farmers on CF (conservation farming) instead of giving them agricultural inputs (The Zimbabwean, 30 January 2019). "*

A similar concern was also raised by the villagers engaged in community gardening under the project who indicated that only part of the promised inputs had been delivered,

> *"We only received a few bags of fertilizer from the project and even the seed was not enough to go round. Some people ended up using their own money (Focus Group Discussion, Chitindiva Primary School, 20 March 2014). "*

The gardeners were also promised wire for fencing around the gardens to protect vegetables from wildlife, which freely roams the area. But this had not been delivered at the time of this fieldwork. In the absence of the wire fence, the gardeners indicated that they had no choice but to engage in cutting down trees for poles to fence their gardens and protect them from thieves, livestock and wildlife, a practice which is deemed illegal by the project proponents

> *"They can give us seed and fertilizer, but without a fence, there is no point growing the vegetables. We will just be growing them for animals to come and feast. So that is why people end up cutting trees for poles to protect their crops (Interview, Butau Village, 7 February 2014). "*

An additional source of mistrust between the community and project proponents is unkept promises to link honey producers to markets. The KCRP also supports beekeeping initiatives where communities place beehives in the conserved forests and harvest honey for sale. The concern over ready markets is accentuated by the fact that the road network linking the ward with major markets is poor. As explained by one participant in Kabidza village,

> *"But the problem is that there are no markets here. Who would buy honey in this rural area? It's not like you can eat it with sadza. You have to take the honey to Chinhoyi, Karoi or even Harare. But transport is expensive and unreliable because of the poor road network. (Interview, Kabidza Village, 7 February 2014).*

"

Thus, the failure by the project to provide the resources as promised has caused the villagers to view it with caution and mistrust, something which has affected compliance.

CONCLUSION

This chapter has presented the KCRP, an initiative for reducing carbon emissions and mitigating climate change while at the same time supporting livelihoods that promote environmental sustainability. The project ideas seem simple and appealing, but turning them into reality has proved complex. Although some positive outcomes have been documented, there has also been some concern over the project's failure to address the daily livelihood needs of the people at the grassroots level who, ironically, are the custodians of the very resources that the project seeks to protect. It is from these resources that these people have eked out a daily living for many years. Asking them to forego, or even criminalising, the only livelihood activities they have known for a long time, without giving them acceptable alternatives is bound to be catastrophic for the project.

It is also clear that memories of the problems associated with previous development projects, especially the more recent and similar CAMPFIRE, have had a bearing on the acceptance of the KCRP by the locals, whose interests lie in securing livelihoods and accumulating wealth. So whatever project is introduced, they will always look at it from the point of view of these interests as well as how they have been affected by previous initiatives, and use that in deciding whether to comply or not.

Five challenges associated with the KCRP were identified by local communities participating in the project as threats to its continued existence. The challenges are associated with lack of transparency and consultation in the making of decisions on project issues. There are also challenges regarding the distribution of project funds to the community and in particular the household as the unit of consumption. The project is also accused of disregarding the existing livelihood activities or providing alternatives that are considered unfavourable by the community. It is also accused of failing to fulfil some of its promises. As it stands, the project is viewed as a threat to household survival as it threatens access to land, natural forest resources, both flora and fauna, things that were readily available to households before its advent. Because of these challenges, the uptake of the project by the locals has been low, thereby threatening its designation as a community-based management scheme.

RECOMMENDATIONS

What therefore is the way forward? This paper recommends the adoption of a balance of needs, where the environment, private entities and local people benefit. This win-win situation may be difficult to achieve but it can be done with sincere engagement and consultation of the communities involved. It is important, therefore, to go back to the drawing board and engage the participating communities in the planning of the project in order to understand prevailing livelihoods and agree on ways of how activities that contradict project objectives can be replaced without much disturbance to individual household survival. For, in the absence of full and committed participation by the community, in a way that benefits individual households, the project's tenure is threatened as people are likely to revert to or even intensify those very activities that compromise the environment that the project seeks to eradicate such as land and forest clearance.

Effective community engagement will foster common property management of forest resources and help avoid a tragedy of the commons which has resulted in uncontrolled environmental degradation. So there is need for all concerned parties to acknowledge that local communities have the potential to save and sustain trees and forest resources and do away with present perceptions that globalise the tragedy – using state, regional and global formulas to solve local environmental and socio-ecological problems – which in most cases deprive locals of forest products from which they survive – creating devastating environmental effects in the long run. What is needed is an appropriate, socio-culturally sensitive local solution that takes into account the rich indigenous knowledge on ecosystems, engaging and empowering locals to collectively manage forests, with suitable and long term incentives. This can be done under the concept of social provenance – an interplay of social, cultural, economic, political, historical and other factors that affect human choice and the use and management of trees and forests. The concept addresses various pertinent questions associated with forest management such as the conditions and perceptions that affect local decisions to manage forests communally, the role of indigenous knowledge and local beliefs associated with the forests concerned. Such social and contextual questions are important for projects like the KCRP. Failure to do this will situate the project in history as one of the many failed top-down solutions, not crafted in-situ. In future, projects must also be assessed in line with their effectiveness, equity and efficiency before implementation, as envisaged in the 3E framework (Angelsen & Wertz-Kanounnikoff, 2008). This will enable project architects to anticipate and deal with potential problems before it is rolled out to the communities.

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CHAPTER **11**

ENHANCING THE CLIMATE CHANGE ADAPTIVE CAPACITY OF COMMUNITIES IN ZIMBABWE: INSIGHTS FROM THE CASES STUDIES (Zimbabwe)

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Source: https://twitter.com/WFP_Zimbabwe/status/1115899434221670400/photo/1

ABSTRACT

This chapter summaries key findings from the case studies and suggest strategies for improving household and community resilience. To build resilient communities, it is important to adopt a multi-stakeholder and multi-sectoral approach and synergize the efforts and bring together the action of a wide range of government ministries and development partners. It is important support smallholder to to diversify income source. The thrust should be to have multiple-farm resources based livelihood system. It suggests that approaches to promote climate smart technologies should be gender sensitive and provide innovative systems of financing adaptation at households. Any effort designed to increase household food security should recognize the importance of integrating and harmonizing agricultural and ecological systems as some household harvest wild vegetables, fruits and even wild birds and fish from the watershed. In this regard we propose the establishment of community-based approaches for managing the agroecological systems that also incorporate indigenous knowledge and apply the principle of subsidiarity. Given the importance of non-timber forests products to female headed households in bridging climate changed induced food insecurity shocks, it is also important to include women in the community based systems management who are responsible for household food security.

Keywords: Adaptation, resilience, gender, agroecosystems, natural resources

INTRODUCTION

Indeed Climate change poses many challenges for poor and vulnerable communities in Zimbabwe. Particularly so, for those that rely for most of their livelihoods on rain-fed agriculture and natural resources. Case studies presented in this book show that poor households have limited capacity to adapt to climate change. This book has also provided evidence that long term changes in temperature and precipitation and increases in climate variability and extreme weather events are already threatening human livelihoods, human health and renewable natural resources. Literature is replete with various methods of climate change adaptation strategies (Zamasiya, Nyikahadzoi & Mukamuri, 2018a). This chapter summarises key findings from the preceding chapters, as well as, suggests strategies for increasing the ability of individuals, households and communities to adapt to climate change and minimize the potential damage on food security, human and animal health biodiversity and ecosystems.

SUMMARY OF FINDINGS

Chapter Two by Mashura (chapter shows that rainfall has a positive and significant effect on cotton, maize and sorghum yields. In addition, results indicate that there is a non-linear relationship between annual rainfall and production of maize, cotton, soybeans and sugarcane. Thus, excessive rainfall could result in reduced maize, cotton and soybean yields, while very little rainfall could be detrimental to sugarcane production. Regarding temperature, the estimations show that it has a significant negative effect on cotton, maize and sorghum yields while the impact is positive for millet and tobacco. There is also a non-linear relationship between temperature and yields of cotton, maize and tobacco. For tobacco, the excess temperature would be detrimental to yields while for cotton and maize which are negatively affected by high temperature very low temperatures can result in crop failures. Irrigation has a positive impact on maize, soybeans, sugarcane, tobacco and wheat, but negatively affects cotton yields.

Pindiriri in Chapter Three demonstrates that there is a high degree of farmers' captivity to traditional technologies caused by insufficient exposure to education and training, lack of credit markets, low incomes, negative perception about modern technologies and inheritance of parental beliefs. The results from the study demonstrate that farmers trapped in traditional production technologies have a higher probability of falling into consumption shortfall during a drought shock. In addition, the results also show that farmers' vulnerability to consumption shortfall is increased by poverty levels, low levels of technical efficiency, increased drought frequencies and being female.

Chapter Four by Zamasiya and others has shown that there is a positive relationship between access to agricultural extension services and household food security. In smallholder farming systems, agricultural extension officers play an important role in the dissemination of information on climate change and agricultural technologies that can be used to address the impacts of climate change on household food security. The study has also shown that there is a positive and significant correlation between household ownership of small livestock and household food security. During poor agricultural seasons, smallholder farmers can easily be disposed of small livestock to raise financial resources to purchase food supplies for their households. Research results from this study have also shown that there is a positive and significant relationship between a household's access to Non-Timber Forests Products and household food security. Smallholder farmers with access to edible wild fruits, indigenous vegetables, edible worms and fish were food secure than their counterparts with the access.

Ruparanganda and Nyikahadzoi in Chapter Five have shown that climate change has reduced the number of months that the household will be self-sufficient from own production of maize, protein and vitamin-rich foods. Although there is a shift towards cultivating drought-tolerant cereals (millet and sorghum), the crops require additional labour during production and also processing into food. This puts female headed households in a difficult situation because they do not always have enough labour. Female-headed households lack human and physical resources to engage in climate smart agriculture, thereby curtailing their ability to increase productivity. Female heads are excluded from engaging in other productivity enhancing strategies such as irrigation. Response strategies include adjusting consumption patterns through reducing the number of meals consumed, altering dietary patterns to include consumption of indigenous fruits and vegetables *(for example, nyemba, nyevhe, masawu, mawuyu*), and selling or exchange of assets particularly goats, sheep and chickens. A new approach of participating in savings clubs and commodity groups was also identified as a useful response strategy.

A study by Mabvurira and Chikwaiwa, Chapter Six focus on the impact of climate change on the livelihoods activities of former commercial farm workers in Mazowe District in Zimbabwe The study shows that after losing their jobs through the land reform program the new black farmers could not fully absorb the former farm workers into employment. Climate change was found to be haunting these landless folks, already vulnerable to poverty due to their landlessness. Livelihoods activities most affected by climate change in these former commercial farms include gardening, brick moulding, gold panning, farming on rented land and petty trade in agricultural and non-agricultural commodities. Limited rainfall attributed to climate change significantly reduced their income which resulted in food shortage.

Mhondera and Mukaro in Chapter Seven argue that the dominant climate change narratives in selected Zimbabwean state media texts communicate negative climate change impacts with minimal emphasis on the calls for climate change mitigation. Media accounts and coverage on climate change mainly construct the phenomenon in terms of weather disasters as shown by the frequency of the words such as disasters and other collocates which include adjectives and adverbs such as *risky, escalating weather events* and *ravaging* among others. However, from the responses, it was established that due to the frequent association of climate change and weather disasters in the media, the "weather" frame might also have been triggered among the audience. Weather and disasters are generally understood as natural phenomena not controlled by humans but are regarded as 'Acts of God'. As a result, the public remains disconnected from it and they are not motivated to act towards reducing emissions as it does not understand its contribution to what is regarded as a naturally occurring phenomenon thereby lacking agency in climate change mitigation. Documented observations made and responses given by the respondents show that climate change mitigation does not rank high on participants' list of concerns in an urbanising context.

In Chapter Eight, Chapungu presents significant changes in temperature and precipitation in Masvingo. The study found a positive correlation between maximum mean monthly temperatures and the prevalence of malaria prevalence. A negative correlation was also observed between the prevalence of malaria and mean monthly precipitation. However, the relationship changes when the mean monthly precipitation is more than 420mm. In general, the drying climate is associated with an increase in the prevalence of malaria. These observations were confirmed by views of the respondents, that observed that climate change has a bearing on the proliferation of malaria. The study acknowledges that several other factors such as population dynamics, government policies, behavioural change, among others, help in modifying disease patterns. Thus, the role of climate change in modifying malaria patterns is more contributory than attributory.

Mangwanya and Dzingirai in Chapter Nine evaluated the performance of the Kariba Carbon Redd+ Project in its efforts to mitigate deforestation. The project focuses on helping farmers to adopt climate smart technologies, sustainable agricultural forest practices such as conservation farming, application of fertilisers and agroforestry. The practices are designed to help farmers to reduce carbon emissions, increase crop yields and cope with the effects of climate change and variability. The initial investment in Climate Smart Agriculture was high while the benefits were not immediate. Communities were expected to adopt CSA and agroforestry practices without transition fund to compensate farmers during the period between establishing CSA structures and the time that they realized the positive impact of agroforestry. This soured the relationship between communities and the proponents of the project. The project is also accused of disregarding the existing livelihood activities or providing alternatives that are considered unfavourable by the communities. It is also accused of failing to fulfill some of its promises such as distribution of subsides fertilisers. As it stands, the project is viewed as a threat to household survival as it threatens access to land, natural forest resources, both flora and fauna, things that were readily available to households before the advent of the project. Because of these challenges, the uptake of the project by the locals has been low, thereby threatening its designation as a community-based management scheme and local participation in climate change adaptation and mitigation initiatives.

The study by Phiri et al, presented in Chapter Ten have shown that the Catch per Unit of Effort was significantly related to fishing effort, lake level and maximum temperature. As fishing effort increased to about 150000 nights fished, there was a significant quadratic decrease in CPUE. However, an increase in effort beyond 150000 nights fished was associated with a significant but linear decrease in CPUE. Furthermore an increase in maximum temperature from below 30 ºC to about 32 ºC was associated with quadratic decrease in CPUE, which was followed by another quadratic but slower rate of decrease in CPUE as temperatures rose beyond 35 ºC. Below lake levels of about 481m, the CPUE was relatively constant but underwent a comparatively fast but linear decrease as lake levels increased from 482 to 484 m, which was followed by a much slower and still linear decrease as lake levels continued to rise. The study shows that Kapenta fishing effort had strong and significant negative impacts on kapenta catches, with increasing maximum temperatures and lake levels also associated with a significant decrease in catches. The study concludes that the increase in fishing effort has been a major factor in the decline of L. miodon catches in Lake Kariba, which has been worsened by warming of the climate.

STRATEGIES FOR IMPROVING RESILIENCE

It has become increasingly clear that even serious climate change mitigation efforts will not adequately prevent the devastating effects of climate change from threatening human livelihoods, livestock and human health and sustainable utilization of natural resources in the short-run (see Chapter Nine by Mangwanya and Dzingirai). It, therefore, means that individuals, communities and policymakers must adapt and increase resilience to the new realities brought by climate change and variability. In this section, we use insight from the case studies to suggest strategies for improving the resilience of households and communities to the effects of climate change.

The multiplicity of effects of climate change

The evidence presented in this book indicates that climate change has broad and significant impacts on household food security, human and animal health. Chapter Four by Zamasiya, Nyikahadzoi and Mukamuri and Chapter Three by Pindiriri show that indeed climate change adversely affects household food security. Chapungu's paper shows that climate change has given rise to the emergency of vector-borne diseases such as malaria. The Chapter by Ruparanganda, shows how female-headed households lost traditional chicken, which they attributed to climate change induced diseases. Mabvurira and Chikwaiwa's findings in Chapter Six also show that climate change has huge impacts on all human livelihoods strategies.

The overarching message from these chapters is that enhancing the climate resilience of any community cannot be the responsibility of a single individual institution. The chapters demonstrate that climate change is multi-causal and therefore solutions should be multi-sectoral. To build resilient communities, it is important to adopt a multi-stakeholder and multi-sectoral approach and synergize the efforts and bring together the action of a wide range of government ministries and development partners. For instance, evidence from this book shows that to fully support vulnerable communities requires the coordination of the Ministry of Agriculture, Ministry of Health, Ministry of Rural Development and the Livestock Production Department.

Enhancing food production systems

Evidence from the chapters in this book has shown that climate change is negatively affecting the agricultural sector. Chapter Five by Ruparanganda and Nyikahadzoi has shown that there are now increased incidences of drought, mid-season dry spells, reduced amount of rainfall and late-onset of rainfall to mark the onset of the farming season. The resultant effect is increased food insecurity and largely among female-headed households. Chapter Two by Mashura has also shown a downward trend in major cash crops as a result of climate change. It is important to note that the decline in food production is happening in a social environment where the population is growing. This implies a negative growth rate of food production while the aggregate demand growth rate is projected at 2.8 per year by 2015 (IAC, 2004). In the absence of a significant increase in per capita production, the implications are that the shortfall will have to be met with massive food imports. Otherwise, the fall in per capita cereal production can lead to serious malnutrition and heightened food insecurity. Therefore, there is great urgency in increasing per capita food production and productivity (production per unit of land). This book uses insights from case studies to show how smallholder farmers can increase food production.

Promote and Support the adoption of drought-tolerant crops

The Zimbabwe Government and its development partners are supporting smallholder farmers to grow drought-tolerant crop such as small grains. Chapter Three by Pindiriri has shown that smallholder farmers remain captured by the tradition of growing maize which the staple food crop. He reiterated that the continued use of traditional production methods in a changing climate would increase farmers' vulnerability to consumption shortfall. This is despite several years of experience showing that maize is severely affected by moisture stress at critical growth stages. Household vulnerability is likely to increase due to increasing drought frequencies. Chapter Five by Ruparanganda and Nyikahadzoi, and also by Chapter Three by Pindiriri have shown vulnerability to consumption shortfall during a drought shock is higher for female headed households than among male headed households. The other alternative is growing drought-tolerant crops such as sorghum and finger millet. However, most smallholder farmers shun and shy away from the growing small grain due to the laborious production and processing associated with these crops. The study by Ruparanganda and Nyikahadzoi stresses that female-headed households are finding it difficult to grow small grains citing high labour demand in production (weeding several times, guarding the crop against aqualia birds, harvesting and threshing and processing (pounding and roasting). Therefore, the promotion of small grains without providing appropriate labour-saving technologies is likely to exacerbate the burden of women and young girls. This is because culturally, women and girls are responsible for processing the small grain into food. In order to support the adoption of drought tolerant small grain, it is important to take into account resource constraints that characterize vulnerable households such as those that are female headed. In this regard, the government and development partners need to support research into the production of labour saving technologies required to process small grain into mealie mill.

The technologies should be low-cost non-labour intensive to lessen the already burdening social caring role that comes with being a woman.

Improve farmers' awareness of the need to adapt

A significant population of Smallholder farmers is aware that climate is changing but they do not see the need to adapt to climate change and variability. As indicated in Mhondera and Mukaro's study, climate change is not well understood. Chapter by Mhondera and Mukaro has shown that people think that climate change is an act of God and therefore nothing can be done to stop it let alone to protect themselves from its effects. The study by Zamasiya, Nyikahadzoi and Mukamuri shows that only 30% know what climate change is and understands the need to adapt. It is evident from Phindiriri' study that there is limited access to information associated with climate change and the need to adopt climate smart technologies. Access to accurate and timely agricultural extension information is, therefore, an enabler of adaptation to climate change as identified by the study by Zamasiya, Nyikahadzoi and Mukamuri. While the extension service is important, it should be delivered in a way that can address the current challenges identified in this book.

Learning-Oriented extension

To address smallholder farmers' lack of understanding of climate change and the need for adaptation as highlighted by Pindiriri and Mhondera and Mukaro. Critical is that extension services ought to facilitate learning with farmers in a way that can be absorbed and understood by farmers. The studies by Mangwanya and Dzingirai and Mhondera and Mukaro have shown that the language used in communicating climate change issues is not effective. Pindiriri identifies high level of illiteracy among smallholder as a major constraint to access and comprehend and use agricultural information. It is important to allow for what Habermass called 'the ideal speech situation' that is immune to repression and inequity. In respect of this, there is need for consciousness in both the communication context and content to adopt persuasive strategies in language use that necessitate the need to undertake actions rapidly to minimize the effects of climate change and variability.

Gender-Sensitive Extension Services

The provision of extension services should take into consideration issues raised by Ruparanganda and Nyikahadzoi, that women have a more cultural constructed responsibilities than their male counterparts, the most important one being that of taking care of children and the sick. Therefore, any training far away from the villages is likely to adversely disrupt the daily chores of women, time and care that they give to children and in some cases, the terminally ill members of their families. We propose that in order for women to access training, it should be conducted in the village or location that is identified and agreed upon by the women themselves

Research has shown that there is a high level of participation when extension is conducted in groups (Mburu, Njuki and Kariuki, 2013). It is also for this reason that we propose that extension be conducted to women groups as opposed to individuals. Therefore, the limited mobility of women away from their homes, and high levels of illiteracy among women may be additional factors constraining to the reception of information.

Reduce the Cost of Adaptation

In some cases, farmers are willing to adapt but the household labour constraint makes it difficult to adopt some climate smart agricultural technologies. In Chapter Five Ruparanganda and Nyikahadzoi have shown that it is difficult for female headed household to adopt labour intensive climate smart technologies such as conservation farming because of labour constraints. Also important is the observation by Mangwanya and Dzingirai that smallholder farmers failed to adopt climate smart technologies such as conservation farming, fertilizer application and agroforestry without external support.

The important role crop diversification plays in guaranteeing household food security for smallholder farmers has long been recognised by researchers. Mutangadura (2005) has identified some labour saving technologies which include: intercropping which reduces weeding time, promoting the use of high yielding crop varieties which are not labour intensive, and conservation farming techniques which include zero or minimum tillage to reduce the need for expensive ploughs and oxen, and promoting natural pest management, thus reducing the need for expensive chemical inputs such as pesticides, which also have adverse effects on health. Mapfumo (2009) corroborates this by noting that crop diversification, as opposed to narrow crop farming, allows farmers to diffuse labour loads through time and it also assures the household of some crop yield in a drought situation.

Support the Adaptation Process

Despite the introduction of climate-smart agricultural technologies in smallholder farming communities, Pindiriri estimates that 44.8% of the households in Hurungwe district is food insecure. In rural Zimbabwe, 80% of the households are living below the poverty datum line of $1.25 per person per day. Failure for CSA to make a meaningful contribution to household food security is attributable to how the technologies are being promoted (Adekunle et al, 2014).

Earlier studies have shown that integrated agricultural researches for development approaches are important to support the adoption of climate smart agricultural technologies (Nyikahadzoi et al, 2012 and Siziba et al, 2013). The approach uses Innovation Systems Approach (Sanginga et al., 2009) to create space for space for public, and private sector investment to develop the agricultural sector. To build a resilient community, we advocate for the inclusive participation of all stakeholders involved in an agricultural system and the commodity value chain. This approach brings in actors that are necessary to provide entry points to practice CSA through funding training and capacity building initiatives. With a right mix of stakeholders it is possible to adequately respond to technical (lack of suitable varieties and technologies) and institutional (support legal and policy framework, availability of adequate trained extension staff, farmer groups) and infrastructural (markets, public roads) factors that might inhibit the adoption of climate-smart agricultural technologies.

Enhancing the enablers of adaptation

Pindiriri (Chapter Three) has shown that inefficient and poor farmers have a higher probability of falling into consumption shortfall during a drought shock. This is also corroborated by Ruparanganda and Nyikahadzoi's study, which shows that female-headed households use recycled crop varieties for maize and do they not have access to inorganic fertilisers. Similarly, Mangwanya and Dzingirai's Chapter Nine shows that without external support smallholder farmers find it difficult to adopt Climate Smart Agriculture technologies. Some studies have shown that without access to inorganic fertilisers, yields can have fallen by 75% and this drives many households into a downward spiral of increased food insecurity, income declines and inability to purchase next season's agricultural inputs (Mapfumo, 2009). Smallholder farmers are caught up in a vicious cycle of poverty characterised by low output, low incomes, low savings and low investments. The main implication of this finding is that poverty cycles continue to put farmers at risk of consumption shortfall during droughts. The study recommends poverty-cycle breaking interventions.

Diversification of Income Sources

Evidence from this book shows the need for smallholder farmers facing challenges from climate change to diversify income source. The thrust should be to have multiple-farm resources based livelihood system. Critical adaptation intervention required to make poor households and female-headed households less vulnerable to the climate change-induced impacts through empowering farmers to diversify household income sources Income-generating programs for the affected households can include support for micro-enterprises, training and access to reliable output market. The most common initiatives in some parts of the country include (a) agro-based enterprises such as gardening, peanut butter making, poultry production, mushroom production, piggery, goat raising, sunflower oil expressing, dairy farming, cattle (b) non agriculture based intervention such as craftwork and small scale manufacturing such as sewing/knitting, embroidery, beadwork, small retailing of cooked food, freezer pops, candle and soap making, (c) adding value to non-timber forest product such as beekeeping and gum tree nurseries.

Improve access to capital

Indeed findings from Ruparanganda and Nyikahadzoi, and Mabvurira and Chikwaiwa have shown that most smallholders are very poor with no capacity to produce surplus that can be sold to generate money to purchase the next season's inputs. Under these circumstances, lenders shun advancing credit to smallholders, as there is no guarantee to get their return from long-term credit. To improve access to finance, we propose to build on the success stories in the study by Ruparanganda and Nyikahadzoi where female-headed households are using Village Saving and Lending schemes to secure their household food security. The government and its development partners can support households to engage in accumulated savings and credit groups. Members of the groups are both owners and users of the facility. Experience has shown that over the years of operation the groups tend to perfect strategies of ensuring that loans are timely serviced (Stringfellow, Coulter, Hussain, Lucey and McKone 2012).). Large financial intermediaries can be encouraged to take advantage of the organisational arrangements of the accumulated savings and credit groups to channel excess loanable funds to households into agriculture, fisheries, aquaculture and other income-generating projects. The fact that members have intimate knowledge of each other and have experience of enforcing loan recovery system is likely to reduce the risk of defaulting on repayments.

Improving the adaptive capacities of the vulnerable groups

The studies by Ruparanganda and Nyikahadzoi and also by Pindiriri show that climate change has a differential impact on different social groups. Climate change and variability impact female and male headed households differently. The studies have shown that vulnerability to consumption shortfall during a drought shock is higher for female farmers and poor households. Mabvurira and Chikwaiwa have shown that former farm workers who were disfranchised of land during the land reform programme are finding it difficult to cope with the effects of climate change. Therefore, using 'one size fits all' approaches and strategies to reduce the effects of climate change among smallholder communities may not be very beneficial to poor and female-headed households. It is important, therefore, to accept that some social groups have situations and circumstances that dictate different approaches to designing appropriate pro-poor technologies. It is important to provide equal opportunities for women and other marginalized groups in accessing resources such as farming inputs, agriculture technology, services and information. This calls for different programmes and policies promoting climate change and variability to be designed to ensure that impacts are addressed in a gender equitable manner in order to increase adaptation to the effects of climate change.

Improve resilience through agroforestry initiatives

While not new, evidence in this book suggests that farming alone may not adequately increase availability and consumption of diverse, safe and nutritious foods for a household. The Chapters by Ruparanganda & Nyikahadzoi and Zamasiya, Nyikahadzoi & Mukamuri have shown that as food becomes scarce households start to source food from Non Timber Forest Products. These include wild vegetables, wild fruits and edible insects. Therefore, the availability of healthy veld or forested areas is very important to ensure household food security. In their study, Zamasiya, Nyikahadzoi and Mukamuri and Ruparanganda and Nyikahadzoi have shown that households that diversify into small livestock are food secure than those that do not have small ruminants. However, the productivity of small livestock depends on the availability of vegetation for fodder and shade. Nemarundwe (2005) and Nyikahadzoi and Zamasiya (2012) predict that when faced with food shortages, poor people adopt unsustainable strategies of exploiting natural resources. Using Hardin's theoretical prediction, commonly owned resources (for example pastures) are susceptible to overexploitation. There is a high risk of overgrazing as more and more households venture into drought tolerant small livestock as they try to manage the effects of climate change

The chapter by Mangwanya and Dzingirai and Phiri et al seem to confirm Nemarundwe's (2005) and Nyikahadzoi and Zamasiya's (2012) prediction and Hardin's theory. Mangwanya and Dzingirai observe the rampant cutting down of trees for settlement, household use, clearing agricultural land and fuelwood has culminated in the massive destruction of forests which are an important carbon sink. This compounds the deforestation caused by climate change, which has resulted in the drying up of large trees at an alarming rate as a result of a reduction in soil moisture due to persistent and extended droughts. The study by Pire et al has shown that the productivity of Kapenta at Lake Kariba is being threatened by climate change. As production goes down, fishers employ unsustainable harvesting practices such as using unregistered fishing boats. In these circumstances, the incentive to conserve is weaker than the immediate rewards of simply extracting. Overexploitation of natural resources coupled with poor or absence of community-based natural resource management institutions has the potential to reduce the capacity of the natural environment to provide food resources and ecosystem services to rural populations that depend on them. To build climate-resilient communities that are food secure, it is important to broaden our understanding of the different food sources and seek ways of enhancing each of them to be more productive.

We are therefore in support the assertion made by Frankenberger, et al (2013) that the management of the natural resources and ecosystem services for sustainable livelihoods is a very important component for improving household food security and building a resilient community. Therefore, any effort designed to increase household food security should recognize the importance of integrating and harmonizing agricultural and ecological systems.

We well-managed agro ecosystems can provide more beneficial services too smallholders and also militate against climate change. According to some authors, a well managed agro ecological system can increase carbon sequestration which in turn increases soil carbon content, improves soil fertility, improves and maintain soil structure, improves water holding capacity/soil water retention, fosters health soil microbial communities, counteracts desertification, makes the soil resistant to both wind and water erosion as well as a climate change mitigation practice (Kane, 2015; Bronick and Lal, 2005; Rawls et al., 2003; Wilson et al., 2009 and Schmidt et al., 2011). In this regard, we, therefore, propose some strategies for improving the functioning of agroecological systems.

Adopt Systems management approaches

The agroecological system has several resources, which include agricultural land, forestry, wetlands and wetlands resources. To date, no national management institutions are dealing exclusively with agroecological systems. Instead, natural resources that are found within the agroecological systems are governed by separate legal and planning structures and different administrative systems (Nyikahadzoi, Mhlanga and Haller, 2013). These legal instruments, though quite comprehensive, tend to conceptualise the different stakeholders in isolation and adopt a narrow sectoral approach to agroecological systems management. It is important therefore to clarify links between national legislations and policy instruments including the forestry, water, land, policies that serve to advance agroecological interests. This may involve facilitating the signing of agreements and memoranda of understanding between government departments or agencies to clarify respective departmental roles and responsibilities concerning the management of the agro-ecological system and promote integrated extension approaches.

Improving the resilience of agro-ecological systems

From Mangwanya and Dzingirai's study, we have seen how top-down and directives in the management of forests lead to the emergency of unsustainable exploitation strategies. Trying to control resource use by controlling human behaviour is necessary but sufficient condition for sustainable utilisation of agroecological systems. It is important to create institutions for managing agroecological systems. We propose the establishment of community-based systems for managing the agroecological systems that also incorporate indigenous knowledge and apply the principle of subsidiarity. That is major decision should be made within the community that would be affected by the decision. Traditional Leaders Act of 2000 can provide legal support for the application of the principle of subsidiarity. The Act acknowledges that issues of democracy and good governance require that communities must have the power to sanction violators. Local communities can only sanction violators who would have violated rules that they perceive to be important or that they participated in formulating. It is therefore important to allow an adaptive evolution of rules and self-regulatory mechanisms within the community.

Reduce dependence on natural resources
It is inevitable that as the effects of climate change increases and the population continue to grow, the dependence on dwindling natural resources is likely to increase. It is, therefore, important to reduce smallholders' dependence on natural resources. For example, the promotion of alternative sources of firewood, which include encouraging the use of efficient cooking stoves, biogas will reduce smallholder's dependence on forestry for firewood. Given the importance of non-timber forests products to female headed households in bridging climate changed induced food insecurity shocks, it is also important to include women who are responsible for household food security. This calls for the adoption of a gender-sensitive perspective to make sure that the concerns of women are taken into consideration at the right time and point of decision-making.

Improving the resilience of fisheries resources
The uncertainties created by climate change in the fisheries sector, as discussed in Chapter Ten by Phiri et al, call for the adoption of a precautionary approach to avoid unacceptable or undesirable situations, taking into account that changes in fisheries systems are only slowly reversible, difficult to control, not well understood, and subject to change in the environment and human values.

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