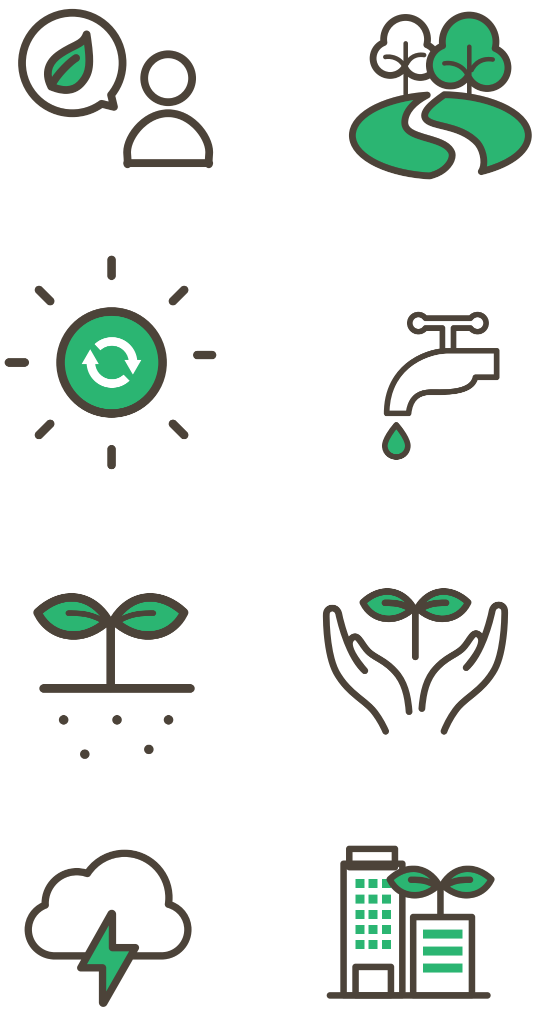
CLIMATE CHANGE IMPACT, ADAPTATION AND MITIGATION IN ZIMBABWE

CASE STUDIES FROM ZIMBABWE'S URBAN AND RURAL AREAS



KONRAD ADENAUER STIFTUNG

Climate Change Impact, Adaptation and Mitigation in Zimbabwe

Case Studies From Zimbabwe's Urban **and Rural Areas**

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CONTENTS

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Nyikahadzoi Kefasi and Mhlanga Lindah

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Foreword

The occurrence of climate change in Zimbabwe and the world over is no longer a debatable issue. Consequently, there is need to prepare communities in both urban and rural setups for resilience. It is particularly important to capacitate our smallholder farmers with knowledge and resources on how to adapt and mitigate climate change impacts in order to reduce food, nutrition and income insecurity, thereby alleviating poverty. Smallholder agriculture, a major driver of Zimbabwe's economy, is primarily rain-fed throughout the country. Climate variability and change consequently place smallholder farmers who have less adaptive capacity in a precarious situation since they have to cope with recurrent droughts, mid-season dry spells, flooding, hailstorms and cyclones. Rural communities also depend on goods and services provided by our natural ecosystems, but unfortunately, these have not been spared from threats posed by climatic variability. This therefore implies that approximately 70% of Zimbabwe's rural population is highly vulnerable to climate change. This reality calls for a shift in research thrusts towards generating innovative ideas that contribute to the building of resilience of smallholder farming communities. Since climate change is now inevitable, key research questions ought to address community preparedness, resilience, influence on policy, early detection and mitigation of natural disasters.

Climate change and variability also present a significant challenge for urban systems in Zimbabwe and the world over, and the effects are expected to intensify over the coming decade. Climate change impacts such as increased or reduced rainfall intensity, storm surges, flooding and urban heat island effects will severely affect urban systems, and the people and services they support. A major response challenge for cities such as Harare will be water scarcity as green infrastructure including wetlands, which form a vital part of the national water supply infrastructure and sequester greenhouse gases, continue to face human-linked degradation through conversion into agricultural units, construction, over-abstraction by boreholes and pollution. Adaptation will most certainly be required to cope with these effects. Urban planning thus has the potential to become a key factor in developing and implementing adaptive responses in urban environments. Plan-making, stakeholder engagement, development management and design standards are some of the tools with potential to develop, deliver and enhance urban adaptation across various scales.

The most encouraging thing is that Zimbabwe has crafted its own National Climate Change Response Strategy (2014) and National Climate Change Policy (2016), and the Education 5.0 framework allows scholars to undertake action-oriented research that improves the livelihoods of communities in the face of imminent negative impacts of climate change. The University of Zimbabwe Strategic Plan (2019-2025) clearly outlines the institution's research trajectory towards generation of knowledge products, goods and services that respond to the needs of industry, commerce and society. The Environment, Climate and Sustainable Development Institute with financial support from Konrad Adenauer Stiftung, is applauded for initiating the mentorship process of bringing together young scholars from various disciplines to champion research linked to climate change at a local level. It is the interaction among disciplines that can bring out the much-needed innovative micro-level technological products and solutions for adoption both on-farm and in urban setups. This is the initial step that will undoubtedly contribute towards the building of appropriate technological innovations appropriate for our urban and rural environments in Zimbabwe. Undoubtedly the information in this book will be useful to all relevant stakeholders.

Professor Florence Mutambanengwe

Executive Director, Research and Innovation University of Zimbabwe

Chapter **01**

Climate Change Impact, Adaptation and Mitigation in Zimbabwe: Overview

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Overview

Climate change is one of the biggest threats facing humankind today (IPCC, 2007a). Shifts of ecological zones, loss of biodiversity and reduction in ecological productivity have occurred as a result of climate change-related stresses (Boko et al., 2007). There is increasing evidence showing a strong nexus between ecosystems, energy, food production, livelihoods and climate change across Africa (Connolly-Boutin & Smit, 2016; Tirado et al., 2015). The imminent threat and impact of climate change has thus caused the interaction of climate change and human economic, social and environmental well-being to become a dominant theme in academic discourse (Lovett et al., 2005).

Climate change is also now a reality in Zimbabwe, as evidenced by changes in temperature and rainfall patterns (Unganai, 2009; Unganai, 1996). The Zimbabwe Meteorological Services Department considers the period from 1980 to date as the warmest since Zimbabwe started recording its temperature (http://weather.utande.co.zw/climate/climatechange.htm). Daily minimum temperatures and daily maximum temperatures have risen by approximately 2.6^{o}C and 2^{o}C, respectively, over the last century (Zimbabwe Meteorological Services http://weather.utande.co.zw/climate/climatechange.htm). Mean surface temperature has warmed by about 0.4^{o}C from 1900 to 2000, and the country is experiencing more hot days and fewer cold days than before as a result of climate change and variability (Brazier, 2015).

Extreme weather events which include tropical cyclones and droughts are now a common phenomenon (Mutasa, 2008). The recent tropical cyclone Idai devastated Zimbabwe's Eastern Highlands in March 2019, and severely affected livelihoods (Chitongo et al., 2019). It caused riverine and flash flooding, loss of lives and general destruction in Chimanimani, Chipinge, Nyanga and Mutare districts (Tsuro Trust, 2019). The rainfall pattern in Zimbabwe is now characterised by spatio-temporal variability, increasing uncertainty in timing and amount of rainfall received, while the frequency and length of dry spells during the rainy season have increased (Brazier, 2015). The frequency of rain days has declined, resulting in droughts becoming a common phenomenon (Makaudze & Miranda, 2010; Ndlovu et al., 2014).

The major concern is that projections for 2050 and until the end of the century show that climate change impacts will even be more devastating for Zimbabwe (Zimbabwe Human Development Report, 2017). It will get drier with total annual rainfall projected to decrease to between 5% and 18%, and will become even warmer with temperature increasing by 3^{o}C-6^{o}C by the end of the century (Zimbabwe National Climate Change Response Strategy, 2014). Warming and water stress present serious challenges in a country where there is high dependence by a large proportion of the population on rain-fed agriculture for food security and livelihoods, and climate-sensitive ecosystem goods and services (Muzari et al., 2016; Chagutah, 2010).

The uncertainty associated with climate variability poses serious challenges to adaptation by communities (Brown et al., 2012). The future climate in Zimbabwe is projected to become less familiar, more uncertain and possibly extreme. Current local practices, processes, systems and infrastructure which have been more or less adapted to current climate conditions, would thus become unsuitable in the future. New adaptation strategies are required to cope with future climatic changes. In 2020, the rainy season had not started by 11 November, which is very unusual, and further indicates that past climate conditions will become decreasingly useful for predicting future climates (Brown et al., 2012). Researchers will thus have to stay abreast of this unpredictability in order to develop appropriate area-specific localised coping strategies. Researchers will also be further challenged to develop localised climate models or gather climate-related empirical data that is downscaled to the lowest possible level to inform local action plans (Chagutah, 2010). Currently, in Zimbabwe, there is a paucity of downscaled climate data despite the fact that climate impacts and vulnerability are highly regionally differentiated (Bhatasara, 2017).

Already shifts have been noted in the country's five agro-ecological zones (Chikodzi et al., 2013), which has led to re-classification of the agro-ecological zones (Table 1.1). The main purpose was to align agriculture practice with the changing climate. The number of natural regions has not changed, but the sizes of natural regions I, IV and V have increased by 106%, 5.6% and 22.5%, respectively. In comparison, natural regions II and III decreased by 49% and 13%, respectively (Mugandani et al., 2012). Zimbabwe's most arid zone, Region V, has been subdivided into Region Va and Vb. Region Vb is the driest and is now deemed to be unable to sustain any form of rain-fed agriculture without being complemented with irrigation, including drought tolerant crops which previously did reasonably well there. Mugandani et al. (2012) attribute the shift in size and positions of the natural regions to the impact of climatic variability and change. For example, Chinhoyi/Chibero environs shifted from natural region 11 to 111, while Kwekwe environs shifted from natural region 111 to IV (Brown et al., 2012). The implication of the reduction of natural regions II and III, which are the cereal production areas in Zimbabwe, points to the possible reduction in food production and thus problems of food security (Mugandani et al., 2012). The economy of the country is adversely affected because the production of maize, tobacco, soya-beans and wheat, the main crops grown in regions II and III, will obviously decline. The development of adaptation strategies has to take cognisance of this shift in order to decrease the vulnerability of agricultural communities to climate change.

Table 1.1: Natural Regions of Zimbabwe (Source: FACTSHEET (2020): Climate Change Redraws Zimbabwe's Agro-Ecological Map, September 22, 2020)

Natural Region	Area 000Ha	% of Total Area	Annual Rainfall (mm)	Farming System
I	613	1.56	>1000	Suitable for dairy farming, forestry, tea, coffee, fruit, beef and maize production
II	7343	18.68	700-1050	Suitable for intensive farming based on maize, tobacco, cotton and livestock
III	6855	17.43	500-800	Semi-intensive farming region, livestock production, cash and fodder crops
IV	13 010 036	33.03	450-650	Semi-intensive region. Suitable for farm systems based on livestock and resistant fodder crops. Forestry, wildlife/tourism
V	19 288 000	26.2	<450	Extensive farming region suitable for extensive cattle ranching. Zambezi Valley is infested with tsetse fly. Forestry, wildlife/tourism

Within any country, vulnerability can vary from village to village and within villages (Eriksen et al., 2005). Vulnerability is a function of the character, magnitude and the rate of climate change and variation to which a system is exposed, its sensitivity and its adaptive capacity (IPCC, 2007a). The most vulnerable are often those who are unable to diversify their livelihoods (Eriksen, 2008). Among the factors that contribute to vulnerability in Zimbabwe are the high levels of sensitivity of the social and ecological systems and the limited capacity to respond appropriately to the emerging threats (Brown et al., 2012). This exacerbates effects of climate change. Other factors include the natural variability of the Zimbabwean climate, high concentration of the population living in rural areas where climate impacts will be strongest, and the lack of capacity to implement adaptation plans and disaster risk reduction measures (including financial resources, technologies, governance and institutional frameworks) (Brown et al., 2012).

Climate change also poses a huge challenge in Zimbabwe because the economy and livelihoods of the poor are dependent on agriculture (Brown et al., 2012). Over 70% of the population that resides in rural areas depends on climate-sensitive livelihoods, such as crop production and livestock rearing (Chagutah, 2010). As such, agriculture's sensitivity to climate-induced water stress is likely to exacerbate the existing problems of poverty and food insecurity among smallholder farmers.

Rural communities also depend on ecosystem services which are already under pressure from overexploitation and poor resource management. Climate change-related negative impacts have already been reported for plants, animals and water resources (Zimbabwe National Climate Change Response Strategy, 2014), and these ecosystem services will come under even greater stress during the anticipated climate change.

The decline or loss of any aspect of biodiversity to the point that it no longer contributes to ecosystem servicing can have drastic impacts on the importance of ecosystem services upon which people depend (Sintayehu, 2018). The projections on the anticipated effects on biodiversity and ecosystems in Zimbabwe are of serious concern. It has been projected that by 2080, areas with high plant diversity are expected to shrink (Zimbabwe's Second Communication to the UNFCCC, 2012). This will also affect Zimbabwe's biodiversity hotspots within the network of protected areas scattered across the country. Biodiversity underlies all goods and services provided by ecosystems that are crucial for human survival and well-being (Sintayehu, 2018). Hannah et al. (2002) reckon that existing static protected areas for conserving wild species will be increasingly reduced as plants and animals respond to changes in climate, with projected shifts in geographical range. It is essential to generate an understanding of the linkages between biodiversity and ecosystem services, and how climate change threats to biodiversity will affect human well-being (Mace et al., 2003).

Rainfall and temperature are key determinants of rangeland productivity (Hoffman & Vogel, 2008). As these variables change in response to climate change, this will affect rangeland net primary productivity (NPP), or the rate of assimilation of carbon dioxide through photosynthesis. The decline in rangeland forage biomass will threaten the multitude of biological and social benefits provided by rangelands (Reynolds et al., 2007), which will have critical implications on the sustainability of livelihoods (Munasinghe, 2009). Low and variable precipitation, extreme temperatures and high evaporative demands will also render rangelands vulnerable to degradation under climate change (Reynolds et al. 2007). In Zimbabwe, net primary productivity is projected to decrease in response to decreases in precipitation, coupled with increases in temperature (Zimbabwe's Second Communication to the UNFCCC, 2012). This implies that forage availability in rangelands will consequently decline, resulting in a reduction in the carrying capacity of rangelands. The fewer animals that rangelands will sustain will not adequately support livelihoods.

The projected increase in veld fire incidences and intensity (Zimbabwe's National Climate Change Response Strategy, 2014) will further cause massive losses of grasslands and also lower the ability of rangeland ecosystems to provide goods and services to society and the environment. The increase in rainfall variability will result in a switch to breeds and species that are better adapted to more marginal conditions (Hoffman & Vogel, 2008). Unless mitigated, there will be greater frequency of loss of livestock assets, reduction in income, and a general reduction in livelihood security. Scholars should continuously generate information on how Zimbabwean rangelands are responding to climate change, how land use practices interact with climate change to influence production, and also develop monitoring systems to unravel ecosystem response to climate change. The information is critical to facilitate the adoption of sound climate-proof micro-level adaptations and technologies by communities.

Due to climate change, food insecurity will be a significant source of vulnerability (Rurinda et al., 2015) for individual households and communities in Zimbabwe. Livelihoods will thus be severely threatened. The projection that under the worst case scenario areas regarded as 'excellent' for maize will decrease from the current 75% to 55% by 2080 (Zimbabwe National Climate Change Response Strategy, 2014), is of serious concern. This shows that communities in Zimbabwe that are currently not well adapted to the prevailing climate change threats will be in worse situations unless appropriate adaptation strategies are put in place. Unless addressed, increased climate variability will result in Zimbabwe failing to meet the Sustainable Development Goals and alleviate poverty. Generally, widespread poverty and limited coping capacity will increase vulnerability (Madzwamuse, 2010).

Climate change adaptation is a principal development challenge in Zimbabwe (Chikodzi, Murwendo & Simba, 2014). Adaptation processes enable societies to increase their ability to cope with an uncertain future by taking appropriate action and making adjustments and changes to reduce the negative impacts of climate change (UNFCCC, 2007). Researchers ought to generate localised information that will enable both natural and human systems to respond to actual or expected climatic changes in order to moderate the effects (Chagutah, 2010). Implementation of appropriate adaptation measures can considerably reduce the projected socio-economic impacts of climate change in Zimbabwe. It is essential to build resilience and increase the adaptive capacity in order to reduce the vulnerability of communities, including people and the ecological components on which they depend. Action research should focus on disaster risk reduction, as well as on how communities can overcome the barriers to uptake of adaptation opportunities (Brown et al., 2012). Higher resilience is anticipated if communities can adopt localised generated knowledge products and technologies to adapt to climate change. More research should thus be generated illustrating micro-level vulnerability (Chagutah, 2010). There is need to build expertise to develop societal impacts and adaptive strategies that address the complex feedback and interactions in biophysical systems (Lovett et al., 2005).

Greenhouse gases (GHGs) such as carbon dioxide, methane, nitrous oxide and fluorinated gases that originate from burning fossil fuels, deforestation and increased livestock farming are considered as major causes of climate change

(IPCC, 2018). Most of the GHG emissions emanate from high income countries. Despite emitting less than 7% of the global total GHG emissions, African countries, including Zimbabwe, have to mitigate against the impact of climate change in order to reduce the vulnerability to extreme weather events caused by global emissions (Reddy, 2015). Zimbabwe's contribution to the climate change problem is very small since its emissions per capita are a quarter of the global average (Brazier, 2015). Its electricity consumption per capita is only about 20% of the global average (Brazier, 2015). However, Zimbabwe is committed to mitigating climate change as illustrated by the country's ratification of the United Nations Framework Convention of Climate Change (UNFCC) in June 1992, and accession to the Kyoto Protocol on Climate Change in June 2009. This was subsequently followed up by Zimbabwe setting up an appropriate policy framework to mitigate the impacts of climate change. The Greenhouse Gas Emission Strategy (2020-2050), a long-term strategy, was set up to mitigate and adapt to the effects of climate change based on Zimbabwe's commitments under the Paris Agreement and its NDCs (Nationally Determined Contributions). It is anticipated that the strategy will work towards reducing the build-up of greenhouse gases in the atmosphere due to anthropogenic activity. Zimbabwe's NDCs to the United Nations Framework Convention on Climate Change (UNFCCC) pledge a 33% per capita emissions reduction (Brazier, 2015). According to Zimbabwe's third submission to the UNFCCC in 2016, Zimbabwe is presently a net carbon sink. The country's estimated emissions are 22,019 $CgCO^2e$, but carbon dioxide removals from the atmosphere through land use, land use change and forestry are estimated at 83,000 $CgCO^2e$ (Brazier, 2015).

Zimbabwe has adopted a National Climate Change Response Strategy (2014) whose main aim is to mainstream climate change in all sectors of the economy. The National Climate Change Response Strategy (2014) seeks to establish specific provisions for dealing with climate change issues, understanding the extent of the threat and putting in place specific actions to manage potential impacts. It seeks to identify risks, impacts, challenges and opportunities in the context of adaptation and mitigation in a range of key sectors of Zimbabwe's economy. The National Climate Policy subsequently developed in 2016 embraces a mitigation trajectory, mainly targeting the energy sector, and intends to climate-proof the country's sensitive socio-economic development sector. The main aim is to integrate action towards the realisation of specific targets, timelines, mandates and allocation of resources and responsibility amongst key stakeholders to realise concrete and implementable steps.

The United Nations REDD+ programme (Reducing Emissions from Deforestation and Forest Degradation), plus the sustainable management of forests, and the conservation and enhancement of forest carbon stocks, is an essential part of the global efforts to mitigate climate change (Norman & Nakhooda, 2015). This permits developed countries to pay developing countries to offset their emissions by giving financial rewards for conserving existing forests (Brazier, 2015). Zimbabwe joined the REDD+ programme in 2011 and has begun building capacity to exploit opportunities from conserving its 15.6 million ha of forests to limit emissions, create income and improve livelihoods. Forest conservation and expansion measures are being instituted and expanded in order to preserve the remaining national forests. Other policies that promote GHG stabilisation include the National Energy Policy (2009), the Zimbabwe Agricultural Policy Framework (ZAPF 1995-2020), the National Water Policy (2012), and the Science, Technology and Innovation Policy (2012). Zimbabwe also managed to submit its three national communications to the UNFCC in 1998, 2013 and 2016. Other initiatives include the formation of the Zimbabwe Climate Change Working Group (FCCWG) and the Zimbabwe Climate Change Youth Network Coalition, both of which were formed in 2009.

Zimbabwe's economy is based mainly on sectors that are vulnerable to climate change, including agriculture, forestry, energy and tourism. Thus, a sectoral approach has been undertaken to institute climate mitigation measures within the various sectors (National Climate Change Response Strategy, 2014). The agriculture sector, which contributes between 10%-15% of the GDP, is largely rain-fed and hence highly sensitive to climate change effects due to its direct dependence on climatic factors (Johannes, 2016). Agriculture affects climate through emissions of GHGs such as carbon dioxide, methane and nitrous oxide (Johannes, 2016). These emissions come directly from the use of fossil fuels, tillage practices, fertilised agricultural soils and livestock manure. It is estimated that agriculture contributes 30%-40% of anthropogenic GHG emissions (Thornton & Lipper, 2013; Gebreeziabher et al., 2014). Three-quarters of the agricultural GHG emissions occur in developing countries, and this share may rise above 80% by 2050 (Thornton & Lipper, 2013), unless abatement measures are instituted. Despite agriculture being a significant source of GHGs that aggravate climate disruption (Parvatha, 2004), the sector provides opportunities for climate change mitigation and adaptation (Johannes, 2016) through reductions of GHG emissions and enhancement of sequestration.

There are many readily available technical agricultural options that can form relatively affordable forms of climate change mitigation options (FAO, 2010). The mitigation options being implemented include switching to climate-smart agriculture in order to reduce emissions, sequester carbon dioxide and help farmers to adapt to the uncertainty of the future climate (Brazier, 2015; IPCC, 2007b). Conservation agriculture is an approach that is being used to sequester carbon, thus mitigating climate change effects (O'Dell et al., 2020). Conservation agriculture has the potential to sequester up to the equivalent of 32% of all man-made GHG emissions (FAO, 2009). The advantage is that conservation agriculture production systems sustain the health of soils, ecosystems and people (Johannes, 2016).

Zimbabwe is focusing its mitigation efforts on improved irrigation, the promotion of resilient cropping and livestock practices, agro-forestry-based adaptation, and climate-smart agriculture (FAO, 2018). The country commits to promoting adapted crop and livestock development and climate-smart agricultural practices. Among the interventions being used is strengthening capacities to generate new forms of empirical knowledge, technologies and agricultural support services that meet climate challenges (FAO, 2018). Scholars have a big contribution to make for this intervention to be effective. The other intervention used is promoting the use of indigenous and scientific knowledge on drought tolerant crop types and varieties and indigenous livestock that are resilient to changes in temperature and rainfall (FAO, 2018). Researchers should continue to gather information to support this intervention. The country is also intervening by developing frameworks for sustainable intensification and commercialisation of agriculture at different scales across agro-ecological zones (FAO, 2018).

A nationally coordinated approach is still required to unpack and implement the National Climate Policy (2016) in order to improve the governance, institutional arrangements and climate change adaptation actions. Scholars should make concerted efforts to generate information from multidisciplinary climate change-related projects in order to provide feedback on the progress made so far in reducing GHGs in Zimbabwe and to guide future action research.

Many individuals, organisations and agencies are engaging in initiatives to mitigate climate change in Zimbabwe (Dodman & Mitlin, 2015). For example, smallholder farmers in Zimbabwe have been implementing practices aimed at mitigating climate change impacts in order to promote food and nutritional security, promote resilience, and increase stability (FAO, 2012). The mitigation measures within smallholder production systems endeavour to buffer production systems against exceptional weather conditions. The measures include the promotion of small grains (FAO, 2012; ICRISAT, 2008), conservation agriculture and the adoption of agro-forestry practices in order to improve livelihoods (Mutambara et al., 2012). Farmers grow drought-tolerant agro-forestry trees as live fences and trees for nutrients. Agro-forestry presents an opportunity to counter the adverse impacts of climate change through the joint action of adaptation and mitigation since forests can sequester carbon and improve soil fertility (Takimoto et al., 2008).

Climate change adaptation is a continuous process requiring location-specific responses (Johannes, 2016). Scholars should continue to generate localised information and also stay abreast of the unpredictability in climate shifts. The 2020 rainy season is a typical case in point where an unusual rainfall pattern is unfolding. Robust multidisciplinary datasets generated by scholars will facilitate the formulation of critically differentiated adaptation strategies and the provision of enhanced climate risk management support to farming households in order to counter impacts of climate change (IPCC, 2007c). There is still a need to build information that will be merged to form a unified body of knowledge that considers discourses of local farmers in rural Zimbabwe to understand climate change and its impacts. Such a body of knowledge will illustrate that the current universal discourse on climate might be scale-specific and should thus be managed as such.

Purpose of the book

This book uses seven case studies to highlight climate change impact, adaptation and mitigation strategies that can be utilised to alleviate the effects of climate change in urban and rural setups. During the 2019 CASS Climate Symposium hosted by the Centre for Applied Social Sciences (CASS) in collaboration with the Konrad Adenauer Stiftung (KAS), the Ministry of Environment, Climate, Tourism and Hospitality Industry lamented the lack of studies on vulnerability and sociology and economics of adaptation, as well as the lack of context-specific mitigation and adaptation strategies and policy mix to guide the process of building climate change resilient communities. Society expects academics to provide guidance and direction in addressing the effects of climate change through the provision of innovative research and publications.

The recently established Environment, Climate and Sustainable Development Institute at the University of Zimbabwe, in collaboration with KAS, launched a special call for research papers aimed at delivering adaptation-related and climate-resilience benefits to most vulnerable communities of Zimbabwe. The information from the research papers was collated into this book. The book contributes towards an understanding of the impact and vulnerability of marginalised communities to climate change-related hazards and also provides an empirical understanding of the science of adaptation.

The Environment, Climate and Sustainable Development Institute with funding from Konrad Adenauer Stiftung facilitated the process of mentoring young Zimbabwean scholars from various disciplines into developing and writing research on climate change-related issues. This was a response to an academic thrust shift to the vision of encouraging academic researchers to become innovators and champions who address challenging national issues. It is critical that Zimbabwean scientists apply their skills and knowledge to human impacts of climate change because of the intricate linkage between livelihoods and the biophysical environment, especially in the rural setup. Other than depending on information from different parts of the world, sustainable development will hinge on how academic institutions successfully initiate a process to strengthen local professional capacity for climate change research. The localised good scientific information generated from the smallest spatial unit possible is expected to build up and finally feed into planning and management. This book is a compilation of papers that were presented at a symposium held on the 9th November 2020 at the Holiday Inn in Harare, Zimbabwe. The Environment, Climate and Sustainable Development Institute at the University of Zimbabwe facilitated the process of developing the papers into book chapters.

Structure of the book

Chapter 1 provides an introductory overview on climate change impact, adaptation and mitigation in Zimbabwe.

Chapter 2 discusses the provision of green infrastructure as an urban resilient strategy in Masvingo city. Green Infrastructure (GI) is one of the most effective and low cost nature-based solutions to climate change. However, this strategy is under threat from the unsustainable consumption of land and natural resources for development purposes which has reduced, fragmented and degraded nature's ecosystem. This study sought to assess the level of provision of Green Infrastructure (GI) in Zimbabwe's urban areas using Masvingo City as a case study. This was achieved by assessing compliance to GI planning principles of considering GI at multiple planning scales, integration of green and grey infrastructure, preservation of ecologically-sensitive areas and connectivity. The study used GIS, field observations and expert interviews for data collection. Results show that there is consideration of GI at macro-, meso- and micro-planning scales, and there is also significant integration of green and grey infrastructure in Masvingo City. Although there is significant protection of ecologically-sensitive areas from urban development, these areas are experiencing degradation due to informal urban agriculture and deforestation. The degradation is eroding the capacity of GI to act as an important strategy of building urban resilience in the face of climate change induced risks. The study recommends the enforcement of environmental legislation and policy that promote the preservation of ecologically-sensitive areas, as well as consideration of urban agriculture in urban land use planning.

Chapter 3 discusses social-ecologically driven threats to the climate change mitigation potential of forests using a case of 3 wards in Murehwa District. Climate change is a reality acknowledged by the scientific community and people in general. Efforts have been directed towards natural ways of mitigating and adapting to climate change. Forests act as a mitigation solution through their ability to sequester atmospheric carbon and convert it into living biomass through photosynthesis. However, socio-ecological systems, including forests, are threatened, and this affects their role in responding to climate change. This study used Geographic Information System (GIS) to assess forest cover changes from 1990 to 2020 in wards 26, 27 and 28 of Murehwa District. The Force Field Analysis technique was used during four focus group discussions to determine forces that either restrain or drive towards maintaining healthy miombo woodlands. Results from GIS showed that forest cover has decreased whilst agricultural land is increasing in all the three wards. Data from focus group discussions showed that there are more restraining forces than driving forces to maintaining healthy forests. The existing institutional arrangements are being overpowered by restraining forces which include poverty, the need to earn a living, population increase, lack of access to alternative fuels, and climate change. If forests are to be conserved sustainably, there is an urgent need to strengthen and build upon the existing drivers such as community involvement and institutional arrangements. Moreover, all stakeholders involved in forest conservation should actively play their part in order to maintain healthy forest ecosystems that can offer climate change mitigation services.

Chapter 4 discusses the implications of climate change on livestock production, with emphasis on understanding the reciprocity and coping mechanisms in a semi-arid environment. Reliance on livestock vis-à-vis crop production is expected to increase in agriculture-based livelihoods of semi-arid areas where the length of the growing season has changed due to climate change. However, while climate change may adversely affect livestock production, animal husbandry is also predicted to significantly contribute to climate change. This chapter uses a mixed methods research design to understand this nexus in Chivi, a semi-arid district in Zimbabwe where crop production has been declining over the past 30 years. Multiple uses of livestock in Chivi indicate the importance of animal husbandry as a livelihood source. Five-year time series analysis using Mann Kendall test showed significant increases ($P<0.05$) in livestock numbers from 2015-2019, despite observed increases in temperature, decreases in rainfall, and subsequent declines in rangeland productivity. This increase in livestock numbers was attributed to government livestock recovery programmes, and autonomous adaptation mechanisms being employed by farmers to cope with the effects of climate change. Some of these mechanisms include cattle translocation to areas with better pastures, as well as the reintroduction of indigenous breeds. An annual methane accumulation emissions of 3.96 Gg in Chivi was observed, representing 11.11% and 2.05% of the entire provincial (Masvingo) and national enteric emissions, respectively. A reciprocal nexus between climate change and livestock production was observed. The need to optimise livestock population cannot be overemphasised, given its contribution to greenhouse gas emissions. The authors recommend smart approaches to livestock production, such as the use of cactus, browse species and fodder banks in order to build climate-resilient communities.

Chapter 5 describes the climate change coping strategies for rural livelihoods and social protection using the case of maize farmers in Gokwe. The aim of this study was to explore the effects of climate change on the food security of smallholder farmers in Gokwe, and then assess the coping strategies employed in response to the food shortages. Parallel exploratory mixed methods were used in undertaking this study in the five clusters of Gokwe South. A total of 1 000 respondents were engaged for the study, with 85.6% completing the questionnaires. Fifteen in-depth interviews, and two focus group discussions with 10 participants each were conducted. The main findings of the study revealed that climate change has led to reduced harvests, changes in food consumption in the past 10 years, and dis-saving practices in a bid to meet social protection needs. The study also established that financial support through remittances, selling of assets and participation in the government's climate change adaptation programmes are some of the responses that have been adopted to mitigate against climate change. It is recommended that a multi-stakeholder partnership should consider employing developmental approaches in order to assist needy, rural, smallholder farmers' households to adapt to environmental shocks and sustain their livelihoods.

Chapter 6 presents local community perceptions of riparian-based ecosystem goods and services under a changing climate using a case study of rural communities living on the edge of Mwenezi River, southeast Zimbabwe. Riparian ecosystem goods and services within semi-arid savannah environments are under the threat of climate change. The study explored local community perceptions of riparian ecosystem goods and services within the context of a changing climate. The objectives of the study were (i) to determine local changes in climatic weather patterns (ii) to establish local community knowledge of the ecosystems services derived from Mwenezi River and (iii) to determine the perceived impact of climate change on riparian ecosystem goods and services and the adaptation strategies that communities use. Household questionnaire surveys (N=159), key informant interviews (N=17), and focus group discussions (N=3) were used to collect data between October 2019 and June 2020. Rainfall and temperature data were analysed using the Mann Kendall test. There has been a monotonic increase in temperature in Chiredzi District, while rainfall has constantly fluctuated. Rainfall has become erratic and late, occurring from October until January. Extreme events like heatwaves and droughts have become a norm in the district. The riparian-based ecosystem goods distinguished by local communities include water, wild fruits, fish, forage for livestock, medicinal plants, fibre and cultural inspiration. Local communities are aware of the impact of prolonged dry spells and excessive temperatures on the availability of ecosystem goods and services. Adaptation strategies used include irrigation schemes, community gardens and livestock rearing projects. Policies that ensure sustainable utilisation of riparian-based ecosystem services should be instituted in order to form strong lasting strategies on climate change adaptation.

Chapter 7 discusses rural communities' understanding of flood disaster risk using a case study of Tsholotsho District, Zimbabwe. Effective disaster reduction begins with understanding disaster risk itself. In order to achieve disaster risk reduction perceptions and practices for disaster risk management should be based on an understanding of disaster risk in all its dimensions of exposure, vulnerability and hazard characteristics. The study sought to establish rural communities' understanding of flood disaster risk in Tsholotsho District, in line with the Sendai Framework for disaster risk reduction (2015-2030). Questionnaires, key informant interviews and focus group discussions were used to solicit information from the affected communities as well as the district Civil Protection Unit. A disaster risk understanding model was developed by the authors which show the three main factors that shape rural communities' understanding of flood disaster risk. These are environmental, social and political factors. The majority of the respondents perceive hazard risk based on their experience with flood disasters, and indigenous knowledge systems emerge as the most important source of flood risk and prediction information. The study recommends the consideration of the top down approach in governance so as to improve communities' understanding of disaster risk. The chapter also advocates for the uptake of indigenous knowledge to complement the scientific knowledge as well as the use of peer to peer education in awareness campaigns.

Chapter 8 explores the implications of climate change in human settlements using Harare as a case study. The implication of the temporal changes in green infrastructure is discussed in relation to climate change. The authors then recommend the development of a strategic framework for sustainable and resilient land use policy, planning and practice in Zimbabwe.

Many studies have been done on how climate change has affected human settlements and how some countries have successfully fought the battle. But, missing in existing literature, generally in Africa, and, particularly, in Zimbabwe, is a critical analysis of existing policies and regulatory frameworks to guide the development of sustainable and resilient human settlements. The bulk of the existing policies sound colonial and have not been updated and adapted to provide solid and reliable guidelines for managing urban and rural land use, and construction. This chapter seeks to reveal the relationship between climate change and human settlements. The chapter recommends the need for a strategic framework for sustainable and resilient land use planning, policy and practice in Zimbabwe. It engages literature review to learn and decipher the direction taken by other countries, as well as document review to examine the existing frameworks to decrypt the disposition of policies and regulatory framework that work for Zimbabwe. It also uses a case study approach to learn from selected local authorities about how they are mainstreaming climate change in their planning, implementation and maintenance of existing infrastructure and superstructures. There is a need for cities to find better strategies to adapt and mitigate the climate change impacts, and it is also high time that land use planning in Zimbabwe grasps resilient approaches to climate planning.

Lastly, **Chapter 9** presents conclusions and recommendations by drawing lessons for the seven case studies.

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Chapter **02**

Provision of Green Infrastructure as an Urban Resilience Strategy in Masvingo City, Zimbabwe

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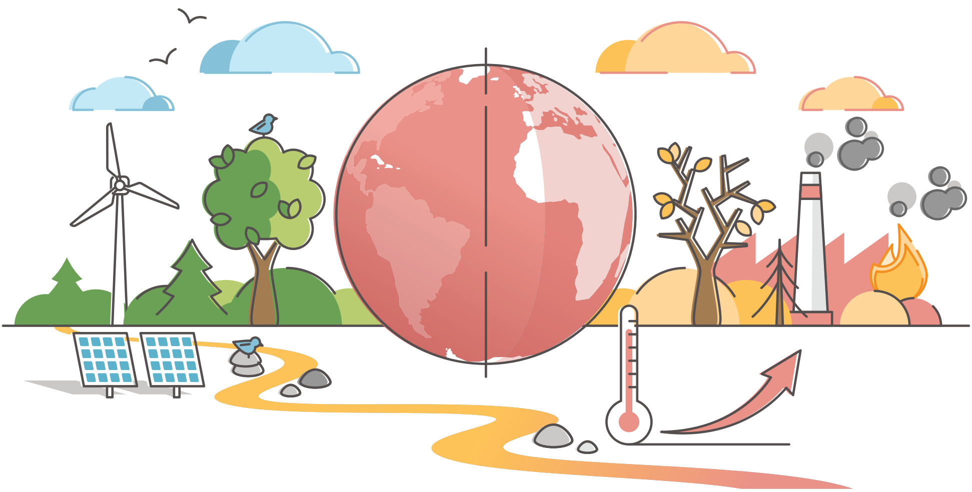


Introduction

Urban areas are vulnerable to current and projected impacts of climate change, with most of the global risks of climate change concentrated in urban areas (SCBD, 2012; IPCC, 2014; Hagen et al., 2014). Climate change induced heat stress, inland and coastal flooding, drought and water scarcity, all pose risks in urban areas for people, assets, economies and ecosystems (IPCC, 2014). The vulnerability of urban areas depends to a great extent on how they have developed in the past and how they are developing now, and urban planning shortcomings such as uncontrolled urban growth and development on open spaces, including wetlands, can increase climate change risk (Hudeková, 2011). At the same time, the increasing loss of earth's goods and services is as equally distressing as climate change (Moberg & Simonsen, 2011). It is estimated that 60% of life-supporting ecosystems services are being degraded or used unsustainably (MEA, 2005). Consumption of land and natural resources for development purposes has reduced, fragmented and degraded nature's ecosystem (Williamson, 2003; Lafortezza et al., 2013).

Urban areas are also experiencing rapid urbanisation, and global urbanisation prospects project that 66% of the world's population will be urban by 2050, with Africa and Asia urbanising faster than other regions (UN-DESA, 2014). As rapid urbanisation, climate change and ecosystem degradation converge, there is growing realisation of urgent need to reconfigure urban areas so that they consume and emit less, are more resilient to environmental changes, and are more sustainable in general (Dawson et al., 2014). Urban development through climate-conscious urban planning and management can help achieve urban sustainability (Kamal-Chaoui & Robert, 2009).

The concept of Green Infrastructure (GI) has been identified as one of the key strategies of sustainable development (Dawson et al., 2014; Williamson, 2003), and its importance grows when we consider its role in climate change response (Hudeková, 2011; Pasquini & Enqvist, 2019). Green Infrastructure is an interconnected network of green space that conserves natural ecosystem values and functions and provides associated benefits to human populations (Benedict & McMahon, 2002). It is one of the resilience investment options capable of increasing the resilience of ecosystems, and of maintaining ecosystem services that would otherwise be reduced through ecosystem degradation (Mazza et al., 2011). GI is important for both climate change mitigation and climate change adaptation, such as temperature moderation, flood control and water management. The capacity of GI to build resilience to climate shocks and variability has already proven to be effective in a multitude of cases around the globe (UNEP, 2014). In the case of African cities, the argument for GI is stronger, given that other forms of infrastructure are often lacking or seriously underperforming (Lindley et al., 2015), and GI is regarded as an essential foundation for sustainable urban futures in Africa (CLUVA, 2013).

GI concept and practice are underpinned by several overarching principles (Mell, 2009) that include planning for GI assets in advance of development, connectivity and multifunctionality, multiple-scale and green-grey integration. Planning and designing green infrastructure in advance of development involves determining where not to develop, that is, pre-identifying ecologically significant lands (Benedict & McMahon, 2002). Connectivity is a property of landscapes that illustrates the relationship between landscape structure and function (Ahern, 2007; Zaręba, 2014). The multiple scale planning involves assessing and planning of spatial configuration of landscape patterns and ecological processes at multiple scales to indicate key points for linkages across the landscape (Ahern, 2007). Multifunctionality refers to the ability of GI to perform several functions and provide several benefits on the same spatial area (Science for Environment Policy, 2012). Green-grey integration principle deals with combining green and grey infrastructure. Urban GI planning seeks the integration and coordination of urban green spaces with other infrastructures, such as transport systems and utilities (Hansen et al., 2017).

Several cities mostly in Europe and the USA have formulated GI plans guided by the GI planning principles (Benedict & McMahon, 2002; Hansen et al., 2017; Nordh & Olafsson 2020). Under the Zimbabwean planning system, GI assets/green spaces are planned for as topical issues in macro- and micro-spatial plans, where green spaces represent one or more of the land use classes, mainly passive and active open spaces (Department of Physical Planning, 1997; Mabaso et al., 2015). However, there is a lack of knowledge on whether or not this urban planning practice is delivering urban green spaces which meet GI principles. This chapter, therefore, assesses the level of provision of GI in Masvingo City, focusing on the level of adherence of urban planning practice to GI planning principles.

Green Infrastructure Concept

GI was identified as one of the key strategies for achieving urban sustainability (Williamson, 2003). In other words, GI should be seen in the context of initiatives that aim to render current land use patterns and practices more sustainably (Davies et al., 2006). According to Benedict and McMahon (2002), GI can shape urban form and provide a framework for growth.

There is no single, universally accepted definition of GI, as the term can be described and assessed in several different ways (Davies et al., 2006; Lafortezza et al., 2013). Thus, different reports and studies present a variety of GI definitions which include the following:

- GI is an interconnected network of green space that conserves natural ecosystem values and functions and provides associated benefits to human populations (Benedict & McMahon, 2002).

- GI is a network of natural and semi-natural features, green spaces, rivers and lakes that intersperse and connect villages, towns and cities. It is a natural, service-providing infrastructure that is often more cost-effective, more resilient and more capable of meeting social, environmental and economic objectives than 'grey' infrastructure (Landscape Institute, 2013).

These definitions are largely consistent and overlapping such that there is a common ground (Davies et al., 2006), with most of the definitions emphasising on GI assets (components, features), and its functions and services as a natural life support system.

Grey infrastructure refers to the built infrastructure, such as buildings (housing and institutional) roads, sewers and utility lines (Benedict & McMahon, 2002). Green and grey infrastructures are sub-systems that together make up the urban landscape (Rouse & Bunsier-Ossa, 2013). There is no fixed boundary between green and grey infrastructure, as GI forms the ground on which gray infrastructure exists (Rouse & Bunsier-Ossa, 2013). In light of this, Davies et al. (2006) came up with a grey-green continuum, where 'green' is defined as a function or facility provided by an asset, even if it is not strictly 'green' in land use terms. The grey-green continuum perceptive suggests that a clear distinction of 'grey' from 'green' infrastructure is not helpful (Davies et al., 2006). The grey-green continuum is similar to a colour chart as one can move through a range of shades (from green to grey) with grey/green in the middle (Figure 2.1).

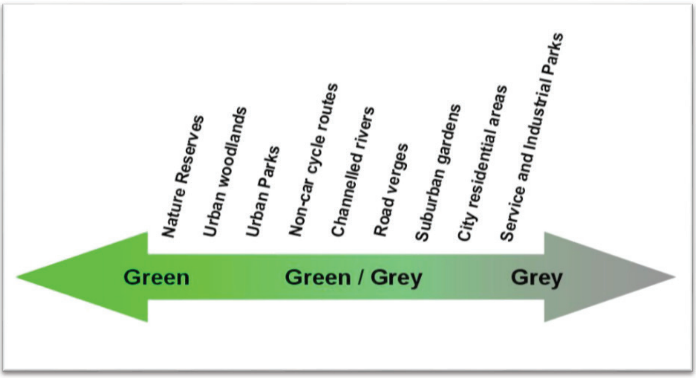


Figure 2.1: The Grey-Green Continuum (Davies et al., 2006).

Urban green (and blue) spaces are incredibly diverse, and a GI typology developed by GREEN SURGE project is made up of 44 elements classified under eight classes.

The eight classes are allotments and community gardens; natural, semi-natural and feral areas; blue spaces; riverbank green; building greens; private, commercial, industrial and institutional green space/green space connected to grey infrastructure; parks and recreation; and agricultural land (Hansen et al., 2017).

GI consists of spatial elements that work together to maintain a network of natural processes, and the elements range in shape, size and function such that each component is important in a different way (Benedict & McMahon, 2002; Lafortezza et al., 2013; Williamson, 2003). The composition and configuration of GI elements directly determine how its assets function. The configuration (spatial arrangements or structural pattern) of GI elements can be defined using a patch-corridor-matrix model. The patch-corridor-matrix model is based on the idea that any landscape mosaic is composed of these three spatial elements. Thus, every point within a landscape is either within a patch, a corridor, or a background matrix (Forman, 1995).

A patch is a relatively homogeneous and nonlinear area that differs from its surroundings, and provides multiple functions including wildlife habitat, sources and sinks for species or nutrients, and aquifer recharge areas (Ahern, 2007). Patches include nature reserves, parks and big lakes. A corridor is a linear element of a particular land cover type that is different in physical structure and content from its context (Forman, 1995; Ahern, 2007). Corridors have many functions that include wildlife habitat, and links of natural habitat patches (Ahern, 2007; Rouse & Bunsier-Ossa, 2013). The corridors can be long strips of forest, rivers, greenbelts and greenways of undeveloped land. They can also be in the form of stepping stones – a series of small, non-connected habitats that facilitates animal movement (Science for Environment Policy, 2012). The matrix represents the dominant land cover type, the overall landscape structure or pattern within which patches and corridors are embedded (Forman, 1995; Ahern, 2007; Rouse & Bunster-Ossa, 2013).

Principles of Green Infrastructure Planning

Urban GI planning is a strategic planning approach that aims to develop networks of green and blue spaces in urban areas, designed and managed to deliver a wide range of ecosystem services and other benefits at all spatial scales (Hansen et al., 2017). GI concept and planning practice is underpinned by several overarching principles (Mell, 2009). Principles are critical to the success of green infrastructure initiatives as they provide a strategic approach and a framework for sustainable use of land that has ecological, social and economic benefits (Benedict & McMahon, 2002). The key principles outlined in green infrastructure literature include planning and designing green infrastructure in advance of development, connectivity (physical and functional), multi-scale planning, multifunctionality and green-grey integration.

Planning and Designing Green Infrastructure in Advance of Development

Under this principle, GI planning is the first step in land use plan formulation, and it involves determining where not to develop, that is, pre-identifying ecologically significant lands (Benedict & McMahon, 2002). Where ecological elements (hubs and links) are identified, planned and maintained in advance of development, the resulting GI network becomes a framework of growth (Benedict & McMahon, 2002; Chang et al., 2012). The principle of planning and designing green infrastructure in advance of development is important, considering the costs of restoring natural systems and the performance of restored and man-made systems as compared to natural systems (Benedict & McMahon, 2002).

Connectivity

Connectivity is a property of landscapes that illustrates the relationship between landscape structure and function ((Ahern, 2007; Zaręba, 2014). Connectivity refers to the degree to which a landscape facilitates or impedes ecological processes or movement, for example, the flow of energy, nutrients, materials and species across landscape elements (Mazza et al., 2011). The connectivity principle means that green infrastructure functions effectively when it is part of a connected system across the landscape (Rouse & Bunster-Ossa, 2013). According to Benedict and McMahon (2002), the desired outcome for all green infrastructure initiatives is a green space 'network' that functions as an ecological whole. The strategic connection of system components is critical to maintaining vital ecological processes and services (Benedict & McMahon, 2002), and the connectivity helps maximise the benefits generated by green infrastructure assets (Landscape Institute, 2009).

Connectivity has two important components, namely, structural and functional connectivity. Structural connectivity is also referred to as physical connectivity, and describes the spatial arrangement of physical relationships between green infrastructure elements (Mazza et al., 2011; Science for Environment Policy, 2012). Functional connectivity refers to the ecological process and behaviour of species in response to the structure of the landscape (Mazza et al., 2011; Science for Environment Policy, 2012).

GI network cannot be attained simply by assembling parcels of marginal land not suitable for development, or from one or two large open spaces on the edge of the development (Town & Country Planning Association, 2008). To create a connected GI system, planners and designers should establish physical and functional linkages across landscape scales (Rouse & Bunster-Ossa, 2013).

Multi-scale Planning

GI networks are visible at different scales, and across urban, peri-urban and rural landscapes (Lafortezza, 2013). According to Davies et al. (2006), GI is not different at varying spatial scale, as it exists at a local scale where its elements (hubs and links) connect to have significance at a scale greater than the local scale. Planners need to adopt a multi-scale approach that involves assessing and planning of spatial configuration of landscape patterns and ecological processes at multiple scales to indicate key points for linkages across the landscape (Ahern, 2007).

Multifunctionality

Multifunctionality is one of the key attractions of GI, and refers to its ability to perform several functions and provide several benefits on the same spatial area (Science for Environment Policy, 2012). The concept means that each GI asset or element can perform different functions simultaneously (Landscape Institute, 2013). This principle builds on the triple bottom line concept line (people, prosperity and planet), where GI is defined by its ability to perform environmental functions alongside economic and social functions (Rouse & Bunster-Ossa, 2013). For example, an urban park's functions can be environmental, such as adapting to climate change or conserving biodiversity; social, such as providing recreational facilities; and economical, such as rising property prices (Science for Environment Policy, 2012). The multifunctionality principle is based on the understanding that these functions are multiplied and enhanced significantly when the green GI elements are planned and managed as an integrated whole, to provide a network whose benefits exceed the sum of the individual parts (Landscape Institute, 2009).

Green-Grey Integration

Green-grey integration refers to combining green and grey infrastructure. Urban GI planning seeks the integration and coordination of urban green spaces with other infrastructures, such as transport systems and utilities (Hansen et al., 2017). This green-grey integration might be a stormwater system that incorporates green roofs, infiltration wells and created wetlands (Zaręba, 2014).

Green Infrastructure Planning Practice

Several cities, mostly in Europe and the USA, have already adopted GI in urban planning practice through the formulation of GI plans after realising its critical role in urban resilience and sustainability. Hansen et al. (2017) provide some of the best GI planning practices in European cities which include Copenhagen, Berlin, Ljubljana and Malmö City. Copenhagen has Cloudburst Management Plan of 2012 which demonstrates an integrated approach in stormwater management, and Berlin's has a city-wide Landscape Programme (LaPro) which is an important strategic instrument for promoting social and ecological connectivity (Hansen et al., 2017). Results of a study by Nordh and Olafsson (2020) involving 24 municipalities of Scandinavia (Norway, Sweden and Denmark) show that all the municipalities had GI strategies, and 60% of them had a GI plan or a similar urban green spaces document.

Few cities in South Africa have begun the adoption of green infrastructure in planning practice, for example, Gauteng City-Region and Cape Town Metropolitan Municipality (Gulati & Scholtz, 2020). However, studies show that urban green spaces are depleting at an alarming rate, with green spaces now occupying a small proportion of the landmass of several urban areas in Africa (Mensah, 2014). Abass et al. (2019) observe that Greater Kumasi has over the years lost most of its greenery owing to the current unsustainable land use practices. According to Gulati and Scholtz (2020), African cities are also expanding in areas with sensitive, critical and fragile ecosystems like forests, low-elevation coastal zones and mega-deltas, leading to a range of adverse environmental impacts such as deforestation, habitat fragmentation, habitat loss and soil erosion. Some of the barriers to investment in GI in African cities include rapid urbanisation, lack of financial resources, lack of priority to green spaces, corruption, uncooperative attitudes of the local people and political instability (Mensah, 2014), lack of clarity and technical guidance, difficulty in quantifying benefits, lack of cross-departmental collaboration, and land use conflicts (Gulati & Scholtz, 2020).

At local level, studies on urban green spaces (Murungweni, 2013; Sithole & Goredema, 2013; Chirisa & Muzenda, 2014; Mutisi & Nhamo, 2015; Musasa & Marambanyika, 2020) have focused on urban wetlands, and the findings show degradation and loss of these ecological sensitive areas due to housing development and urban agriculture. According to Chirisa and Muzenda (2014), ecological-based urban planning in Zimbabwe is facing several challenges which include uncoordinated planning approaches, ineffective policies and legislative frameworks, weak institutional settings, financial constraints, out-dated planning standards and regulations, poverty, lack of environmental stewardship, and lack of political will, among others. However, there is a lack of knowledge on the capacity of Zimbabwe's urban planning practice in delivering urban green spaces which meet GI principles. This chapter, therefore, assessed the level of provision of green infrastructure in Masvingo City, focusing on the level of adherence of urban planning practice to GI planning principles.

Description of the study area and methodology

The study adopted a mixed methods approach where both quantitative and qualitative methods where used.

Study Area

The study area is Masvingo City, the provincial capital of Masvingo Province. The city is located within Masvingo District in the south-eastern parts of Zimbabwe (Figure 2.2). The City of Masvingo has an estimated population of 100 000 people (ZIMSTAT, 2012). Masvingo, with an annual rainfall of 600 mm, has hot and dry weather throughout the year, except during the summer. Mucheke and Shagashe rivers run close to the city centre, and they act as de facto boundaries of the central business district. The study's focus was within the current official boundary of Masvingo City which encompasses an area of 9 420 hectares.

Masvingo City was purposively selected after considering the important urban planning processes taking place in the city. The city has initiated the review of the existing 1993 Master Plan, with the aim of preparing a new long-term master plan that is going to guide future developments. The new master plan is expected to tackle contemporary challenges that include climate change. The plan can address climate change risk through climate-conscious land use strategies, for which GI is one of the most effective and low cost options. Therefore, an assessment of GI provision in Masvingo City is expected to inform these important urban planning processes in the city.

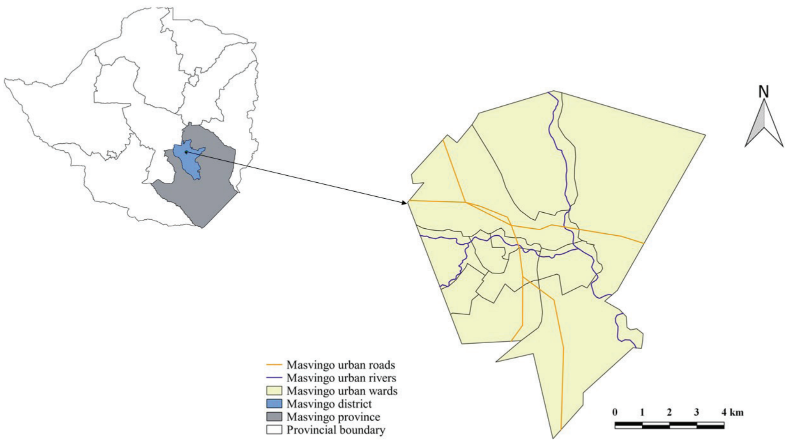


Figure 2.2: Location of the Study Area

Research Methods

To assess the provision of GI at multiple planning scales, three planning scales were considered, namely, macro-, meso- and micro-scales. At macro-scale, the Masvingo City Master Plan of 2012 was used to assess the consideration of GI at this planning scale. The master plan was scanned, georeferenced and digitised in GIS to create a map with two main land use classes of grey and green infrastructure. To assess provision of GI at meso-scale, a map of existing grey and green infrastructure was created using maps of existing developments in Masvingo City. These maps were georeferenced and digitised in GIS and then updated using a 2020 Google Earth image and field visits. Using the created map of existing grey and green infrastructure, the provision of GI at meso-planning scale was then assessed using selected local districts (central business districts, low-density and high-density residential districts). Provision of GI at micro-scale was also assessed through a field visit to observe presence or absence of tree canopy, gardens and landscaping on randomly selected residential, institutional, commercial and industrial stands/properties.

The physical connectivity of green spaces was assessed using the map of existing grey and green infrastructure. This was achieved through assessing the spatial distribution of green spaces, classified as patches/core and links (corridors and stepping stones). The presence of a link connecting two or more evenly spatial distributed patches represented physical connectivity, and isolated or unevenly spatial distributed patches represented less or no physical connectivity.

The integration of green and grey infrastructure was assessed using the master plan, maps of existing developments, the Google Earth image of 2020, and field observations. The focus was on assessing the availability and condition of key features of green-grey integration which include road buffers and reserves, servitudes for power lines, railway lines, sewer lines and other utilities. We also observed the availability of GI features within the built-up area or grey infrastructure. This was also augmented with expert interviews with Masvingo City Council officials, to understand the availability and implementation of policies that guide green-grey integration.

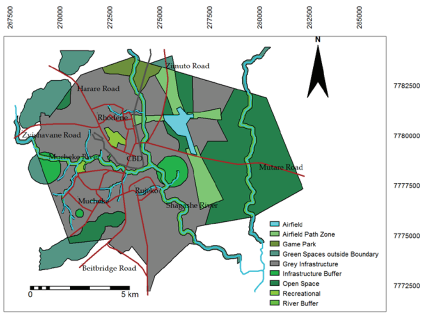
Ecological Sensitive Areas (ESA) in Masvingo City were mapped in GIS using data that was obtained from the Master Plan, 2020 Google Earth image and field visits. The focus was on identifying natural watercourses, wetlands and nature reserves. Guided by the Environment Management (Environmental Impact Assessment and Ecosystems Protection) Regulations of 2007, we created a 30 metres buffer zone on all the mapped natural water courses and wetlands. The map of ESA with 30 metres buffer zones was then overlaid on the map of existing developments to determine the level of encroachment by physical developments into ESA. Field visits were also carried out to observe the condition of ESA as well as human activities such as urban agriculture, being carried out on these areas.

Results

This section focuses on the presentation, analysis and discussion of the study findings on the level of adherence of urban planning practice of Masvingo City to GI planning principles, namely, multi-scale, green-grey integration, connectivity and protection of Ecological Sensitive Areas.

Consideration of GI at Multiple Planning Scales

The urban spatial planning of Masvingo City is done at three planning levels/ scales, namely, macro- (city), meso- (local) and micro- (site) planning scales. At macro-level, development is guided by the Municipality of Masvingo Master Plan of 1993 that was updated in 2012 (Figure 2.3).



This master plan makes the provision of green infrastructure by reserving an area for a game park; an airfield restriction path zone; buffer zones around major infrastructure such as power sub-stations and wastewater treatment plants; river buffer zones for Mucheke and Shagashe rivers; sports fields; and major open space patches located in the northern and eastern side of the city. The total land reserved for green spaces constitutes about 44% of the total land within the current official boundary of Masvingo City (Table 2.1).

Table 2.1: Provision of GI at Macro-Planning Scale in Masvingo City

Land Use Classes	Zoned Area (Ha)	Percentage of the Total Area
Airfield	138.90	1.47%
Airfield Path Zone	514.08	5.46%
Game Park	205.17	2.18%

Grey Infrastructure	5139.43	54.56%
Infrastructure Buffer	278.82	2.96%
Open Space	2422.08	25.71%
Recreational	74.50	0.79%
River Buffer	647.18	6.87%
Total	9420.16	100%

At meso-planning level, development is guided by the preparation and implementation of local plans which include residential, commercial and industrial layout plans. There is provision of GI at meso-scale in Masvingo City, evidenced by green spaces in all the residential areas of Masvingo. These green spaces include sports fields and buffer zones of major roads and rivers. For example, in Rhodene low-density residential area, the total area occupied by green spaces (which include sports fields, open spaces, and buffer zones for major roads) constitutes about 29% of the total Rhodene area (Figure 2.4). However, there was less consideration of Green Infrastructure (GI) in the spatial planning for Masvingo Central Business District (CBD), and the only notable green spaces are the urban recreational park at the Civic Centre and the green median of two boulevard roads (Robert Mugabe Road and Greenfields Street).

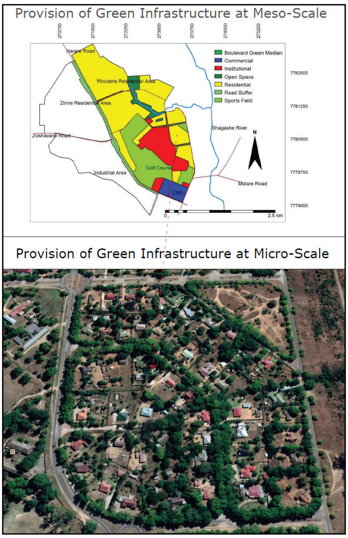


Figure 2.4: Provision of GI at Meso and Micro-Planning Scale in Rhodene Low-density Residential Area – Masvingo City (Source of Image: Google Earth, 2020)

At micro-scale, development is guided by site plans for individual stands or properties. There is a significant provision of green infrastructure at this site scale, with most of the institutional (for example, schools and colleges) and hotel sites in the town practising some form of green landscaping. Basing on field observation and Google Earth images, individual residential stands (high, medium and low) have significant tree canopy of different trees species which include fruit trees. Rhodene residential area has several trees along the streets and on individual residential stands (Figure 2.4). Most of the CBD streets are lined with jacaranda and palm trees.

These results show that there is a consideration of GI provision in Masvingo at macro-, meso- and micro-planning scales. However, there is little evidence to suggest a deliberate linkage of green infrastructure to grey infrastructure on layout plans on the master plan.

Level of Integration of Green and Grey Infrastructure in Masvingo City

This principle is strongly linked with the provision of GI at micro-/site scale. The urban form of Masvingo City shows that there is significant integration of grey and green infrastructure. This integration is achieved through the provision of road buffers on most of the major roads (primary and district distributors). There are also few roundabouts with green circles, and boulevards roads (roads with green medians) in Masvingo CBD (Robert Mugabe Street and Greenfields Street) (Figure 2.5) and Rhodene low-density residential area (Carry Street and Duranta Avenue). Most of the roads outside the CBD were designed with road reserves, which allow the channelling of stormwater from the carriageway into the natural environment.

Figure 2.5: Boulevards Roads in Masvingo CBD (Source: Google Earth, 2020)

There are also urban planning standards and regulations which allow the integration of grey and green infrastructure, which includes servitudes for power lines, railway lines and sewer lines. The power line servitudes are guided by the Statutory Instrument 177 – Electricity (Public Safety) regulations of 2018, for example, 10 metres for 11 and 22 kilovoltage (kV) power lines, 15 metres for 33 kV, and 30 metres for 66-132 kV power lines. The railway servitude is around 40 metres, and this is provided for in the Masvingo City Master Plan. These servitudes are mainly open spaces where trees are cleared without disturbing other important ecological functions.

The building lines standards promote the integration of grey and green infrastructure on-site or on individual stands. For example, when developing residential property, the developer is expected to leave a certain distance from each stand boundary, and this distance varies with the density of the residential area. Therefore, this standard minimises the creation of impervious surfaces in residential areas. Also, the standard stand sizes for urban schools – 3,5 hectares for a primary school and 7,5 hectares for a secondary school accommodate sports fields and gardens which are part of the GI typologies. There are also residential and agricultural stands in Masvingo City and its peri-urban, which represent the integration of green and grey infrastructure, for example, residential plots in Morningside.

Based on observational findings, it was noted that Masvingo City lacks green buildings with features such as green or living roofs and walls, and blue roofs for harvesting rainwater. There is also limited integration of green-grey infrastructure in terms of sustainable transportation as evidenced by the absence of pedestrian and cycle tracks lined with vegetation. However, there are a number of informal pedestrian tracks passing through open spaces, for example, there are informal pedestrian tracks linking Rujeko and Mucheke high-density areas with Masvingo CBD.

Level of Physical Connectivity of Green Spaces in Masvingo City

The green infrastructure patches in Masvingo City include an area reserved for a game park in the northern side of the city and open space patches in the east which were pre-identified in the master plan in Figure 2.3. The corridors are mainly in the form of buffers zones of rivers (Mucheke and Shagashe) and major roads (Figure 2.6).

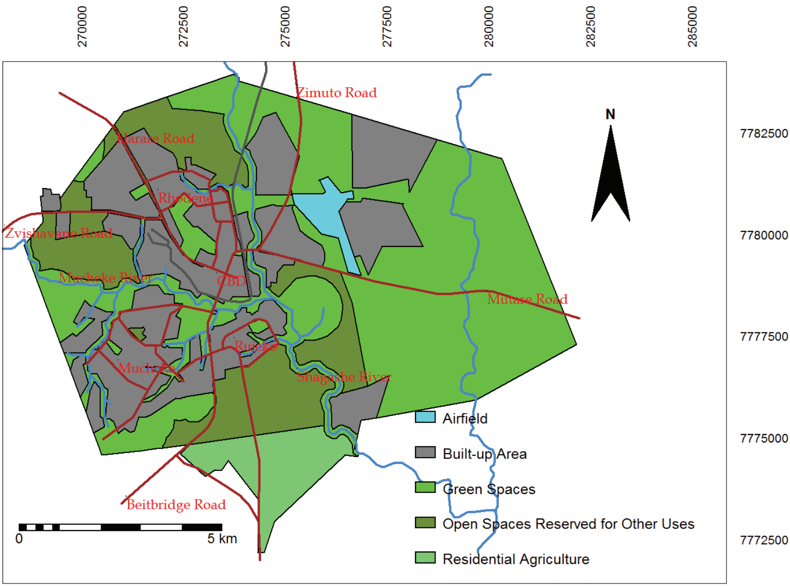


Figure 2.6: Existing Green Patches and Links in Masvingo City

Although there are corridors (buffers zones) that link green patches across the landscape, the physical connectivity of the green spaces is compromised by the uneven spatial distribution of patches which are concentrated in the northern and eastern side of the landscape (low- and medium-density residential areas). There are only small green patches in the southern and western part of the city where the high-density residential area of Mucheke is located. Open spaces reserved for other uses also form part of the existing green patches, constituting about 16% of the total land area of Masvingo City. The physical connectivity of green spaces is therefore expected to decline with future development of these existing open spaces reserved for other uses.

Preservation of Ecological Significant Areas (ESA)

The ESA in Masvingo City include Shagashe Game Park, Mucheke and Shagashe rivers, small natural water courses, and wetlands located in the southern residential areas of Masvingo urban. The game park and Mucheke and Shagashe rivers and their buffer zones are provided for under the master plan. Therefore, there was pre-identification of Ecologically Significant Areas and, according to Benedict and McMahon (2002), this is the first step in urban spatial planning.

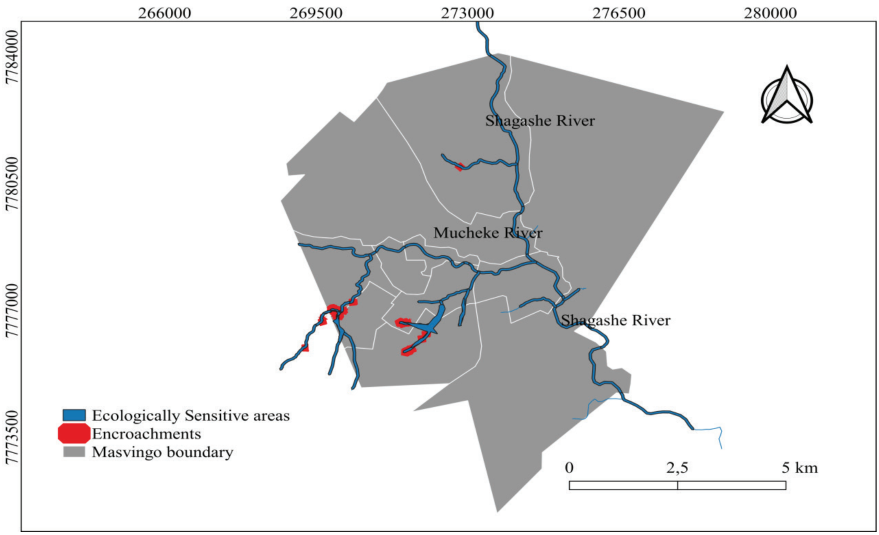


Figure 2.6: Spatial Distribution of Wetlands within Masvingo Urban

The results show that most of these ESA have been protected from urban development, with only a few cases of encroachment by housing developments into the prescribed 30 metres wetland and river buffer (Figure 2.6). The area covered by encroachments was 0.3462 ha. These encroachments were identified in Mucheke high-density residential area. The encroachments have a negative bearing on the essential services provided by Ecological Sensitive Areas in the regulation of urban flooding. Most houses that are within the 30 metres buffer zone are highly exposed to urban flash floods which are projected to increase in frequency and intensity due to climate change.

Through field visits, it was observed that informal urban agriculture is being practised on most of the green spaces across the urban landscape, and this is threatening ESA, such as wetlands and natural watercourses. Urban agriculture is causing the degradation of ESA through the clearing of natural vegetation for farming purposes, and this is exacerbated by cutting down of trees for firewood to cope with energy challenges. Most of the open spaces are only left with isolated trees, and their tree canopy is now less compared to the built-up areas.

Discussion

Masvingo City is performing fairly well in the provision of GI at multiple planning scales as evidenced by consideration of GI at macro-, meso- and micro-planning scales. The master plan managed to pre-identify Ecologically Significant Areas which include natural water courses buffers and the nature reserve/game park. Therefore, through this city-scale land use plan, urban planning of Masvingo City managed to identify where not to develop in line with what Benedict and McMahon (2002) view as the first step in land use plan formulation. The results also show that there is considerable integration of grey and green infrastructure through buffer zones and servitudes of major infrastructure. However, some of the low impact development such as unpaved roads in residential areas is mainly a result of lack of resources to fully develop the road infrastructure rather than strategic integration of grey and green infrastructure.

The results show that physical connectivity is being compromised by the uneven distribution of green spaces. The absence of big patches in the Mucheke high-density residential area might increase the vulnerability of the area to climate change induced risks, such as extreme weather events. These results support the argument that climate change risks are unevenly distributed and are generally greater for disadvantaged people and communities who live in poor-quality housing and exposed areas, without essential infrastructure and services (IPCC, 2014). The resilience of these communities is further compromised by the lack of resources which would enable them to quickly and effectively protect themselves from extreme weather patterns (Kamal-Chaoui & Robert, 2009). In addition, the green patches are at the edge of the city boundary, and the Town and Country Planning Association (2008) argues that GI network or connectivity cannot be attained from one or two large open spaces on the edge of the development. Considering that connectivity quality is essential for sustainable and resilient urban regions, this low connectivity of green spaces in Masvingo City may have adverse implications on the resilience of the city, particularly the low-income communities of Mucheke high-density residential area.

Masvingo City is mainly facing a challenge of degradation of green spaces from urban agriculture and deforestation. Degradation of urban green spaces is associated with loss of ecosystem services, which has negative implications on GI as an urban resilience strategy. Degraded green spaces have lower capacity in terms of local temperature regulation, carbon sequestration and regulation of flood events (Lindley et al., 2015). Urban agriculture also negatively affects water resources through eutrophication evidenced by high levels of algae bloom and water hyacinth in Mucheke and Shagashe rivers.

This degradation of green spaces due to informal urban agriculture is both an urban land management and planning problem. It is an urban land management problem in the sense that there is failure to enforce environmental regulations that prohibit farming activities on ESA, such as wetlands and river banks. This is an urban land use planning problem in the sense that there is a failure to plan for urban agriculture. Several studies (Mendes et al., 2008; Meenar et al., 2017; Horst et al., 2017) have highlighted the need to integrate urban agriculture in urban planning to avoid problems of unregulated urban agriculture. If properly planned, urban agriculture represents one of the key GI typologies with an important role in climate change adaptation. Some municipalities in developed countries have recognised urban agriculture as an integral part of planning and zoning practices, and they have created necessary policies to facilitate its integration in the urban planning practice (Meenar et al., 2017). The failure to recognise urban agriculture in Masvingo City and other urban areas in Zimbabwe supports the argument by Chirisa and Muzenda (2014) that urban planning in Zimbabwe is facing several challenges which include ineffective policies and out-dated planning standards and regulations.

Conclusion and Recommendations

The study findings show that there is consideration of GI at macro- and micro-planning scales, and there is also significant integration of green and grey infrastructure in Masvingo City. There is less physical connectivity of green spaces across the urban landscape despite the presence of patches and links mainly due to the uneven distribution of the patches on the urban landscape. Although there is less depletion of ESA from physical urban development, these areas are currently experiencing degradation due to informal urban agriculture being practised on most of the open spaces in the city, including wetlands and river banks. The degradation of green spaces greatly compromises the use of GI as a strategy of building urban resilience in the face of climate change induced stresses and shocks. The study also concludes that the management of green spaces is as important as its provision through spatial planning. The study recommends the enforcement of environmental legislation and policy that promote the preservation of green spaces, particularly Ecological Sensitive Areas; the review of planning standards and regulations; and the consideration of GI for urban infrastructure funding. Lastly, the study recommends the recognition of urban agriculture in urban land use planning.

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Chapter **03**

Social-ecologically Driven Threats to the Climate Mitigation Potential of Forests: A Case of Murehwa District

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Introduction

Climate change is a reality (Ontl et al., 2020; Pacoma, 2019; Kerr & Wilson, 2018) which is posing great challenges to human life and therefore requires urgent attention (Nunes et al., 2020; Tomaselli et al., 2017). According to Nunes et al. (2020), the widely accepted cause of climate change is the increase in carbon dioxide concentration in the atmosphere, which is mainly a result of anthropogenic activities such as burning of fossil fuels. Efforts to mitigate the effects of climate change have been directed towards sustainable ways of reducing atmospheric carbon concentration (Nunes et al., 2020). Forest ecosystems act as a possible solution for mitigating against climate change (Hamilton & Friess, 2018; Shahbazi & Nasab, 2016) because of their carbon sequestration potential (Patil & Kumar, 2017).

Background

Healthy forests are an important component of the terrestrial carbon cycle that captures and stores large percentages of atmospheric carbon in the form of organic carbon in vegetation, forest biomass and soil (Hui et al., 2017; Liverman, 2009; IPCC, 2007). Natural forests fix carbon in their biomass, an environmental service for which forests are now recognised (Yan et al., 2018; Giri & Madla, 2017; Patil & Kumar, 2017). At the global scale, the total amount of carbon that forest ecosystems store exceeds the amount of carbon in the atmosphere (Seidl et al., 2018; Hui et al., 2017; Federici et al., 2017; Lal, 2005). Thus, forest vegetation has the capacity to reduce the increase of atmospheric carbon concentrations (Lawson, 2020; Mahmoud & Gan, 2018; Ward et al., 2018).

Mature and intact forests are the most dense carbon stocks and the most bio-diverse natural ecosystems that offer other benefits to the society and the economy (Mackey et al., 2020; Moomaw et al., 2019). Terrestrial sequestration of carbon is accomplished through forest practices that enhance the storage of carbon, and these practices include conservation, restoration and the establishment of new forests (Ontl et al., 2020; Kumar et al., 2017; Schahczenski & Hill, 2009). It is more ideal to conserve existing forests for carbon sequestration owing to the fact that young trees and newly planted forests need many years before they sequester carbon dioxide in substantial amounts (Moomaw et al., 2019). Zimbabwe is a member of the Reducing Emissions from Deforestation and Forest Degradation and Enhancement of Carbon Stocks through Forest Conservation and Management (REDD +) international initiative (Ribeiro et al., 2020; Bond et al., 2010). The REDD+ programme aims to maintain existing forests through strategies such as continued sustainable management and local stewardship of forests, enhancing the sequestration of carbon through afforestation, reforestation and restoration of degraded forest land (vonHedemann et al., 2020).

Forest loss or degradation does not only cause increased carbon concentration in the atmosphere, but also results in loss of ecosystem services that are offered by forests to the environment and people (Blaser, 2010). Deforestation contributes to climate change because it reduces the net flow of carbon from the atmosphere into forests, both in the present and future (Nunes et al., 2020; Curtis et al., 2018). Any change in the carbon balance of forest ecosystems has a strong impact on the atmospheric carbon concentration (Bradshaw & Warkentin, 2015).

The role of local communities is central to the success of maintaining healthy forest ecosystems which, according to Jenkins and Schaap (2018), are free from invasive species, and also provide several services that include climate regulation, productive soils and many of society's needs, such as economic processes and cultural values.

Protection of healthy forest ecosystems is now considered as increasingly important as an approach to mitigate against the negative effects of climate change (Wood et al., 2019). Conservation of forests is vital to the quality of the environment and society, since they provide many services to humans (Stocker et al., 2014). Forests are part of the social-ecological systems in the sense that they exhibit strong intricate interactions between social, economic, ecological, cultural and political components, which underpins the exchanges between nature and human society (Petrosillo et al., 2015). These exchanges in the social-ecological systems have an influence on the well-being of the environment. The purpose of this study was to determine the drivers and restraining forces in the social-ecological system and their influence on the status of forest ecosystems.

Conceptual Framework for Understanding the Relationship between Contextual Factors which Determine the Well-being of Forests

Figure 3.1 is a modified framework adapted from Oakerson (1990). The framework provides the basis for analysing contextual factors that determine the status of common-pool resources which include forests in the communal areas of Zimbabwe.

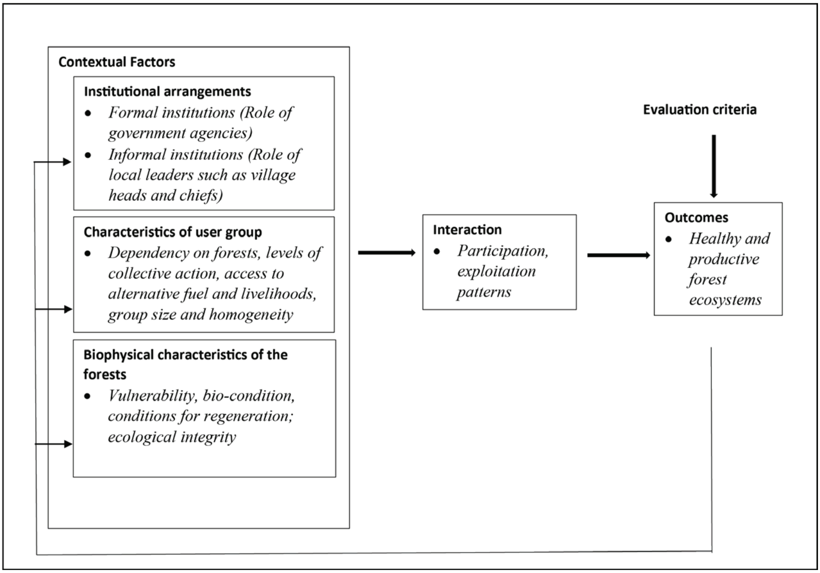

Figure 3.1: Framework for Understanding the Relationship between Contextual Factors which Determine the Well-being of Forests (Adapted from Oakerson, 1990)

Institutional Arrangements

Hardin's tragedy of the commons argues that unless common-pool resources are transferred to government control, overexploitation is inevitable (Frischmann, Marciano & Ramello, 2019; Al-Fattal, 2009; Hardin, 1968). The theory by Hardin (1968) suggests that where there is no state intervention in management, natural resources are accessed freely and selfishly by everyone, and 'ruin' is the ultimate result. However, Ostrom (2005) and Murphree (1991) critique Hardin, arguing that sustainable utilisation of forests can be achieved when local communities are involved in the management of resources available to them. For instance, Ostrom (2009) observes that communities that are involved in designing rules of managing the commons have high chances of success in achieving sustainable use. Nyikahadzoi and Zamasiya (2012) argue that local communities can only sanction violators who would have violated rules that they participated in formulating. Roka (2019) and Chingaipe et al. (2016) emphasise the importance of allowing an adaptive evolution of rules and self-regulatory mechanisms within the community as pre-requisites for sustainable utilisation of natural resources such as forests. However, local institutional initiatives alone failed in natural resource conservation in many countries, including Zimbabwe (Milupi, Somers & Ferguson, 2017).

The failure of centralised mechanisms in the management of natural resources led to the search for a viable and sustainable approach (Nabane & Matzke, 1997). Other scholars have suggested that adaptive co-management, where both government and local communities are engaged in the management of forests, is a sensible endeavour that has the potential to achieve more sustainable forest utilisation (Islam, Ruhanen & Ritchie, 2017; Diver, 2016; Cinner et al., 2012; Ostrom, 1990). Mbuvi and Kungu (2019) and Oosterveer and Vliet (2010) highlight that the principle of subsidiarity (that is, major decisions should be made within the community that would be affected by the decisions) must be upheld.

Characteristics of Resource Users

Sustainable management of forests depends upon the characteristics of resource users. One of the characteristics of resource users, which determine their ability to maintain healthy forest ecosystems, is group size (Cox, Arnold & Tom's, 2009). For users to sustainably exploit forests and work together to achieve common good, their group size should be relatively small in order to increase the levels of interaction (Olson, 1965). Homogeneous resource user groups that share important social, cultural, or economic characteristics have high chances of sharing common interests, and this increases chances of cooperation towards sustainable natural resource management (Fearon & Laitin, 1996). Agrawal and Angelsen (2009) argue that communities that are well-off may not be highly forest-dependent since they can access alternative sources of fuel and livelihood strategies. Therefore, relatively small, well-off communities with shared norms, trust, past successful experiences of cooperation, and interdependence among group members, have better chances of sustainably managing forests available to them (Agrawal, 2007; Larson, 2003; Agrawal, 2001).

Biophysical Characteristics of Resources

Forests that can be sustainably managed are those that exist in a properly functioning ecosystem with necessary conditions for regeneration (Angermeier & Karr, 1994; Oakerson, 1990). Factors such as optimum temperatures and adequate precipitation affect the extent, structure, species composition within forests, and regeneration capacity (Kleinschmit et al., 2015). In a study by Tucker, Randolph and Castellanos (2007), it was found that forests that could regenerate naturally, as well as biodiverse and productive forests, were associated with higher annual rainfall. Thus, sustainable management of forests occurring in areas where there is adequate rainfall, moisture and optimum temperatures is likely to be high with the possibility of high levels of plant biodiversity (Lonn et al., 2018; Agrawal & Chhatre, 2006). Forests that are biodiverse have high chances of resisting the adverse effects of climate change and, as a result, they have a greater chance of being maintained as healthy forests (Jactel et al., 2017; Agrawal & Angelsen, 2009). Therefore, forests that can be sustainably managed are those that are biodiverse, can also occur in areas with high rainfall, and have predictable regeneration capacity, since such forests constitute an incentive for effective management and sustainable exploitation.

Socio-ecological systems are able to maintain an equilibrium when the off-take is equal to the forest growth. Forests are under threat from climate change, which is resulting in the drying up of large trees in miombo woodlands at an alarming rate. The increasing demand for forest products is also posing serious threats to forest ecosystems. It is important, therefore, to establish the current drivers and threats to maintaining a healthy forest ecosystem both as a carbon sink and also to meet the increasing demand for forest products by marginalised rural communities. The research reported in this chapter used Geographical Information System (GIS) to track changes in forest cover and land use over time. The Force Field Analysis was used to establish the points of view of local actors on the emerging drivers and restraining forces that support or threaten the health status of the forests. Murehwa's wards 26, 27, 28 were used as a case study to assess land use and land cover changes and threats to the well-being of forests.

Description of the study area and methodology

Study Area

The study was carried out in wards 26, 27 and 28 in Murehwa District (Figure 3.2). The District is located in Mashonaland East Province in Zimbabwe at 17.65°S; 31.78°E. The altitude is 1300 metres above sea level. The main vegetation type in the area is miombo woodlands. The area has been experiencing climatic variability.

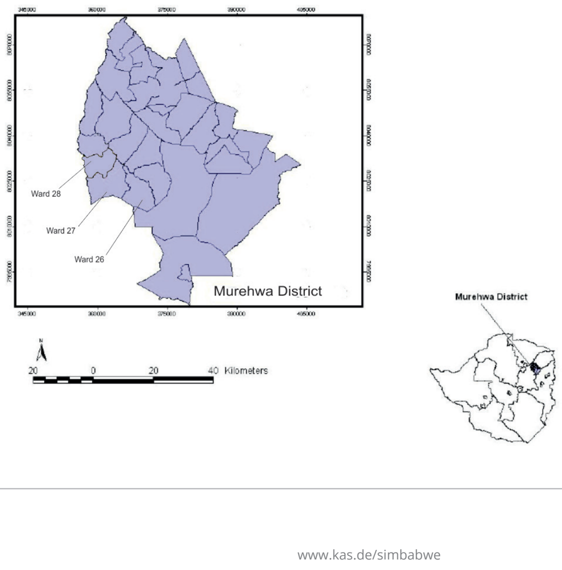

Figure 3.2: Location of Study Sites in Murehwa District

Research Methods

Study Site Selection and Sampling Methods

The study was carried out in Murehwa's wards 26, 27 and 28. Four villages were purposively selected for focus group discussions due to their closeness to forested landscapes. One village was selected in each of the wards 28 and 27, and two villages were selected in Ward 26 owing to the fact that it has more forests than the other two wards. Purposive sampling was also used to identify focus group participants. Participants were mainly farmers relying on rain-fed agriculture, gardening and other livelihood strategies that depend on forest resources. The ages of participants ranged between 35 years and 65 years. Targeted participants were those who had lived in the study area for more than 25 years such that they had historical knowledge of developments within the forests. These participants were identified with the help of village heads. A total of four focus group discussions were conducted. Each focus group discussion was made up of eight participants to ensure effective participation.

Data Sources, Collection Methods and Analysis Procedures

The study adopted a qualitative methodology. In order to map changes in forest cover over time in the areas under study, the researchers used Land Use Land Cover change maps (LULC) spanning from 1990 to 2020. Geographical Information System (GIS) and remote sensing were used. Administrative shape-file boundaries were digitised in a GIS environment. Satellite images from Landsat series of Landsat 5 were used for 1990 and 2005. Landsat 8 images were used for 2020 images because Landsat 8 images for 1990 and 2005 could not be found. Landsat images which were used were captured in June for easy identification of forests and cropland owing to the fact that farmers would have harvested their crops. The classification was done using random forest classifier in Google Earth Engine. For GIS maps to be produced, Landsat image series of Landsat 5 and 8 were processed using Aeronautical Reconnaissance Coverage Geographic Information System (ARCGIS) to come up with LULC map layouts. Estimations of crop land and forest land were calculated using the total number of pixels in the study area layout. Each pixel represented 900 m2.

The Force Field Analysis was used to establish enhancers and threats on forests. Figure 3.3 shows the driving forces which push towards maintaining a healthy forest ecosystem, as well as restraining forces which push against maintaining a healthy forest ecosystem. This approach assumes that in every situation there are driving and restraining forces and, in this case, these forces determine the ultimate status of the forest ecosystem.

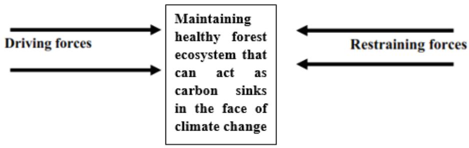

Figure 3.3: Force Field Analysis

Focus group discussions were conducted at village level where participants listed driving and restraining forces for maintaining healthy forests. The purpose of the discussions was explained to all participants in each focus group using the local Shona language. Subsequently, a brainstorming process was carried out to determine the driving forces that would result in healthy forests that can act as effective carbon sinks. Each participant was given an opportunity to speak. All the driving forces were read aloud to ascertain what the respondents had said. Each driving force was given a score according to the participants' perceptions, from 1 (weak) to 3 (strong). Afterwards, another brainstorming process was carried out to determine the restraining forces that threaten the existence of healthy forests that can act as effective carbon sinks. Restraining forces were read aloud to ascertain what the respondents had said. Each restraining force was scored according to the participants' perceptions, from 1 (weak) to 3 (strong). The time taken during each focus group discussion ranged between one hour and, one and half hours.

Data collected from focus groups was tabulated and translated, and the calculation of average scores for the mentioned forces was done by adding different values which were given to the forces by focus group participants, and then divided by the number of instances the statement was mentioned. Reasons which were given by the respondents for scores which they assigned to different forces were audio-recorded and these audios provided explanations for the origin and the severity of the forces.

Results

Temporal Forest Cover Change in Ward 26, 27 and 28 in Murehwa District (1990 -2020)

The changes in land use cover in Murehwa's wards 26, 27 and 28 from 1990 to 2020 are shown in figures 3.4 to 3.6.

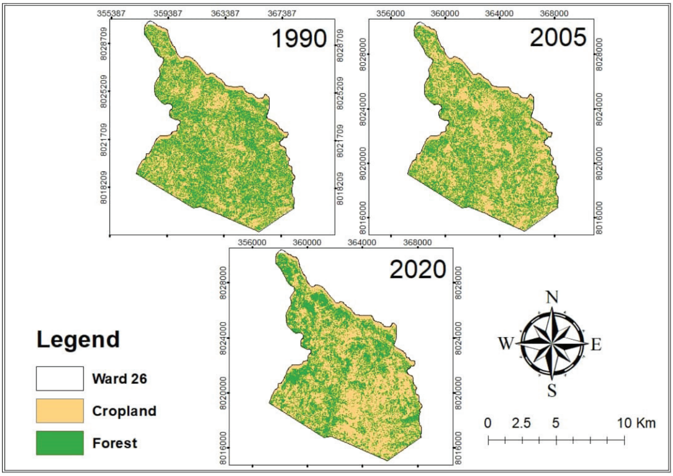

Figure 3.4: Land Use Land Cover Change in Ward 26 of Murehwa District (1990-2020)

Ward 26 experienced forest cover loss, but the major decline occurred between 2005 and 2020 (Figure 3.4). The south-eastern part of the ward was the most affected as it showed greater forest cover loss and a greater increase in crop land than the other parts of the ward.

Forest cover and land use changes in Ward 27 showed that forests occur mainly to the west of the ward (Figure 3.5). The loss of forest cover in the ward was minimal.

Figure 3.6 shows decrease in forest cover and land use changes in Ward 28. Although forests are disappearing in the whole ward, the 2020 map is showing some regeneration of forests, especially on areas that were completely bare on the central part of the map.

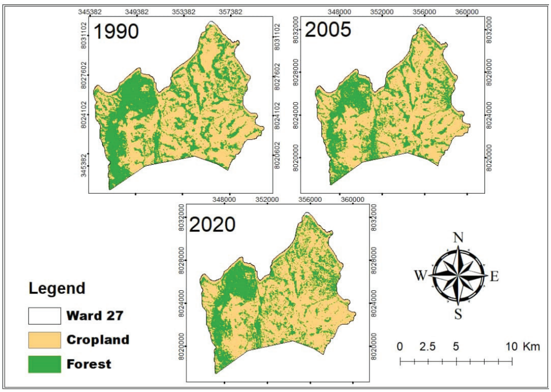

Figure 3.5: Land Use Land Cover change in Ward 27 of Murehwa District (1990-2020)

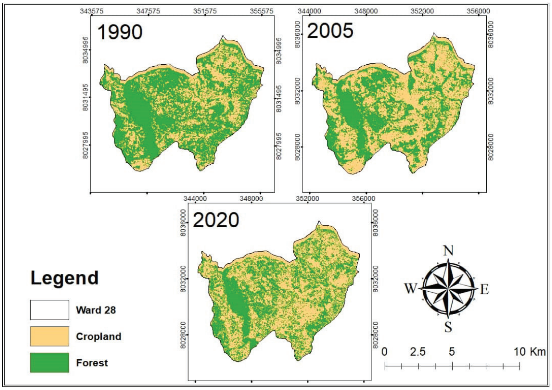

Figure 3.6: Land Use Land Cover Change in Ward 28 of Murehwa District (1990-2020)

Table 3.1 summarises changes in land use in the three wards between 1990 and 2020. Forest cover has been decreasing in all the three wards over a period of 30 years. The highest rate of forest cover loss of 27% occurred in Ward 28, followed by Ward 26, with a forest cover loss rate of 19% and, lastly, Ward 27 had the least rate of forest cover loss of 14%. As forest cover decreased, crop land or agricultural land increased in all the three wards. The highest rate of crop land increase of 43% occurred in Ward 28, followed by Ward 26 with a 20% increase, and the least being Ward 27 with a 9% increase. Results from Table 1 show that forests are under threat. Therefore, the key question is: What is causing the forest cover to decrease from 1990 to 2020?

Table 3.1: Summary of Forest Cover and Crop Land Changes in Three Wards in Murehwa District (1990-2020)

WARD	Forest Cover (ha)				Crop Land (ha)			
	1990	2005	2020	% Change 1990-2020	1990	2005	2020	%Change 1990-2020
Ward 26	4951.17	4096.62	4021.83	-19%	4690.89	5545.44	5620.23	+20%
Ward 27	4813.65	4161.6	4138.56	-14%	7245.9	7897.96	7920.99	+9%
Ward 28	4328.1	3182	3156	-27%	2712.9	3858	3885	+43%

(-) Decrease (+) Increase

Driving and Restraining Forces for Maintaining a Healthy Forest Ecosystem

The results of the Force Field Analysis which was used during focus group discussions to establish local people's understanding of enhancers and threats to the existence of a healthy forest are shown in Table 3.2.

The forces that were considered to be strong in driving towards a healthy forest ecosystem are effective co-management, active local leadership and community involvement in maintaining healthy forest ecosystems (Table 3.2). The mean scores show that the driving force that had the highest strength was active local leadership. The forces that were considered to be strong in restraining towards a healthy forest ecosystem are community level poaching, population increase, climate change driven low rainfall, and the growth of invasive species (Table 3.2). The mean scores show that the restraining forces that had the highest strength were community level poaching and population increase.

Table 3.2: Driving and Restraining Forces for Maintaining a Healthy Forest Ecosystem in Wards 26, 27 and 28 of Murehwa District

Driving Forces	**Mean Score**	**Objective:** **Maintaining a Healthy Forest Ecosystem**	**Restraining Forces**	**Mean Score**
1.Effective co-management arrangements between Environmental Management Agency and local institutional arrangements	2.7± 0.6		1. Community level dependency on forests as people cut down trees for firewood to use at home, to burn bricks and cure tobacco	3 ±0
2. Active local leaders who are teaching community members the importance of conserving forests	2.75 ±0.4	**Maintaining a healthy forest ecosystem**	2. People from other villages poach forest resources in other people's forests	3 ±0
3. Community involvement and participation in forest management	2.7 ±0.6		3. The population is increasing and people are clearing forests land for settling and agricultural activities	3 ±0
			4. Climate change driven invasive species and low rainfall which is preventing the regeneration of forests	2.75 ± 0.4
Total	**8.15**			**11.75**

(1=weak 2=medium 3=strong)

Driving Forces

Co-management is one of the key drivers that can be instituted in order to maintain healthy and productive forests. Co-management arrangements can be put in place to improve the enforcement of management regulations governing forest use (Driving Force 1). According to focus group participants, the Environmental Management Agency (EMA) has formed a co-management arrangement with local communities. Participants indicated that the co-management arrangement had the potential to reduce poaching of timber from the forest since communities report violators to EMA. Poachers are then arrested by EMA. However, some participants alleged that EMA will not always come to apprehend timber poachers due to lack of human and financial resources necessary for putting up an effective enforcement and surveillance system. Nevertheless, participants in one of the focus groups acknowledged that the few arrests by EMA in the past instilled a sense of fear of apprehension in the community. The group participants agreed that the apprehension of those who violate forest management regulations is very infrequent because EMA relies on whistle-blowers for information. However, participants argued that the fear of losing important social relations makes it impossible to self-regulate and report violators to responsible authorities.

Local institutional arrangements are perceived as playing a significant part in maintaining healthy forests (Table 3.2). A traditional leader who was part of one of the focus groups pointed out that as local leaders in Zimbabwe they are empowered through the Traditional Leaders' Act Chapter (29:17), to be the custodians of natural resources, including forests. The duties of local leaders include ensuring that natural resources, including forests, are exploited sustainably through teaching, and controlling and preventing the degradation, abuse or misuse of natural resources within their jurisdictions (Driving Force 2). Participants said that their local leaders were organising days on which community members would go into the forest to remove invasive species in order to create space for the growth of new miombo trees. A ward councillor who had attended one of the focus group discussions also said that ward councillors are working with traditional leaders to remind their subjects on the importance of conserving forests during community meetings.

There is evidence of collective action to maintain the integrity of the forests (Driving Force 3). Participants indicated that they are working together towards the maintenance of healthy forests. The communities are removing Lantana camara, an invasive species that disturbs the regeneration of forests. Participants from one focus group discussion reported that there were days in which village members would go into the forests to remove invasive vegetative species. Participants were of the view that community efforts presented an opportunity for maintaining healthy forests. Participants also affirmed that communities were actively involved in the maintenance of healthy forests through self-policing against overexploitation and illegal extraction of forest resources.

Restraining Forces

The restraining forces that are working against the maintenance of a healthy forest ecosystem are listed in Table 3.2. Difficult conditions have forced villagers to disregard EMA and local leaders' forest management rules and regulations designed to maintain a healthy forest ecosystem. The main restraining forces include pressure on forests as a result of poverty, population growth and the need to meet household food and income security.

Smallholder tobacco farmers utilise firewood harvested from the forests to cure tobacco. They have no alternative source of fuel. Participants in one of the focus groups indicated that for farmers to break the vicious cycle of poverty, they have resorted to tobacco farming which has resulted in excessive cutting down of trees for firewood to cure tobacco. Other participants observed that due to the lack of other income-generating strategies, farmers were mainly engaging in growing tobacco in order to raise income for household expenses. Tobacco curing consumes a lot of firewood, resulting in the loss of many trees. Participants also stressed that the majority of farmers engaged in tobacco farming illegally extract large amounts of wood from forests.

Participants also highlighted that people overexploit forests in order to supplement household income. Trees are harvested to burn bricks. Small businesses for moulding and selling bricks are rampant. Focus group participants indicated that brick moulding has grown into a popular income-generating strategy among most rural able-bodied men, particularly the youth. It was reported that brick moulders were causing forest degradation in two ways, namely, (i) clearing land on which they would carry out brick moulding activities and (ii) cutting down trees for firewood to burn their bricks. The burning of bricks required large amounts of wet firewood resulting in large miombo trees being selectively removed.

Communities are also highly dependent on forests as a source of firewood for household use (Table 3.2, Restraining Force 1). Participants were aware that to keep a stable forest, there should be a balance between off-take and the forest's ability to regenerate. Participants affirmed their desire to conserve forests for the future generation, in spite of the fact that they do not have viable alternative sources of fuel. The majority of them cannot afford alternative fuels such as liquefied petroleum gas. They have also not been introduced to other efficient cooking stoves.

According to focus group discussion participants, the very few households that could afford alternative fuel could not readily access it since the providers are only found in urban areas and at a few growth points. The challenge, according to participants, is accentuated by the Forestry Commission's failure to supply local communities with trees for planting to restore degraded forests through afforestation and reforestation. Participants argued that plantations which were started by communities from trees they got from the Forestry Commission used to reduce pressure on indigenous forests since communities got alternative sources of firewood. One focus group participant emphasised that the involvement of the Forestry Commission in supporting reforestation was essential in maintaining the balance between extraction of firewood and regeneration of forests.

During the focus group discussion, participants pointed out that there is massive land clearing in the area to support increasing agricultural activities. This is supported by figures 4, 5 and 6 that show an increase in crop land by 43%, 20% and 9% over a period of 30 years in wards 28, 26 and 27, respectively. One of the major reasons for the expanding of agricultural land was that farmers are practising extensive agriculture and need more land in order to increase production so as to self-insure against food insecurity. Participants stated that smallholder farmers were no longer getting good yields because their soils were exhausted. Poor yields were also exacerbated by the adverse effects of climate change which include poor rainfall and high temperature. This has caused smallholder farmers to clear more forests to create virgin land that is naturally fertile. Farmers also expected their yields to increase with the increase in the land under cultivation.

The expansion of agricultural land is also on the rise especially in wards 26 and 28 owing to the increase in population. The rapid increase in the population is causing farmers to encroach into forest land. The large number of people who settled in forest land were those who had left their parents' household to start their own families. These need land to settle and for farming purposes. Participants also stated that pressure on forests emanated from urban to rural migration since people were moving back from towns as a result of unemployment. It was also expressed by one village head who was part of the focus group that as the pressure increases, local leaders are forced to allocate people land in the forests. Efforts by local leaders and government agencies to manage forests sustainably are weakened by the pressure emanating from natural population increase and urban to rural migration.

During the focus group discussions, participants explained that devastating and persistent droughts are now forcing the smallholder farmers to cultivate in the few wetlands that exist in the area, in order to escape hunger. The wetlands gardens are fenced by poles and branches extracted from forests in order to protect crops and vegetables from livestock. The smallholder farmers cut a large number of trees for poles and branches to fence their gardens. Having a garden in wetlands ensures better yields and provides household income after selling the produce both during the dry and wet seasons. The demand for poles and branches for fencing is being accentuated by the fact that most smallholder farmers are poor and cannot afford to buy barbed wire and fence.

Maintaining healthy forest ecosystems was hindered by the encroachment of Lantana camara in miombo woodland (Restraining Force 4). According to participants from one focus group discussion, Lantana camara suffocates native miombo trees and impedes the regeneration of seedlings, which leads to a decrease in the population of miombo. Although community members were trying to control the invasive species, it grew faster than the rate at which it was being removed.

Climate change and climate unpredictability have also resulted in rainfall variability, which is one of the major restraining forces which threatens the existence of healthy forests. Participants highlighted that recurrent droughts have negatively affected the health of their forests. Focus group participants said that persistent and extended droughts have resulted in the reduction in soil moisture, which has resulted in the drying up of large trees at an alarming rate. Participants also confirmed that tree seeds were germinating after a rain event, but they were not growing into mature trees because the young trees would not have long taproots to access the water table which would be very low

Discussion

One would expect forest ecosystems to be healthy in the three wards due to the availability of local institutional arrangements since local leaders encourage people to conserve forests. Local communities have the ability to self-regulate when they realise that their resources are in danger of depletion (Yuliani et al., 2018), the assumption being that resource users recognise the intrinsic value that is in natural resources such as forests. However, forests in the area are under threat due to community overdependence on them for firewood, crop land and fencing materials. The overdependence on forests renders formal and informal institutional arrangements incapable of conserving forests and managing utilisation patterns. As such, forests are failing to regenerate.

The need for survival, coupled with desperation, poverty and lack of alternative sources of fuel, is putting forests under threat of degradation. Efforts from EMA to limit illegal extraction of forest resources are hindered by the lack of human and financial resources. As such, co-management mechanisms are ineffective. Even in the presence of co-management arrangements between local communities, local leaders and government agencies, forests remain under the risk of further degradation due to the fact that what drives people to overexploit forests is stronger than the need to conserve them. The findings are supported by Oyanedel, Gelcich and Milner-Gulland (2020), who argue that individuals have a tendency of disregarding sustainable exploitation of resources when opportunities presented by legitimate activities are inadequate and incapable of sustaining them. Resource users may be well aware of both short- and long-term impacts of overexploitation; but they may not have an incentive to think of other resource users (Colin-Castillo & Woodward, 2015). Human dependence on forests is a multifaceted phenomenon because forests provide a diverse stream of benefits to humans, a fact which puts forests at a vulnerable position (Garekae, Thakadu & Lepetu, 2017). It is consequently difficult to maintain healthy forests in areas where people overly depend on forests for their survival. Thus, forests remain in danger due to individual choices and the need to earn a living which is a strong restraining force to the maintenance of healthy forest ecosystems.

Natural resources can be managed sustainably through community involvement, collective action and cooperation (Flanery et al., 2020). The results show that communities can work together to achieve a common good such as controlling an invasive species and forcing compliance to forest management regulations. The results from focus group discussions and LULC change analysis show that the efforts by communities were not enough since forests are disappearing. The rate at which invasive species are growing and disturbing the regeneration of native *miombo* woodlands exceeds community efforts to control the invasive species. Compliance to regulations was not universal since only those who had forests complied. Forests belonging to villages that comply were threatened by external poachers who disregarded forest management regulations. Compliance or non-compliance is an instrumental decision that is made by individuals after calculating gains when rules are complied with, and the costs of not complying, given the probability of being apprehended (Acheampong & Maryudi, 2020). Poachers seem to be gaining more from their illegal activities since chances of being apprehended are very low.

Ecological integrity and the ability of forests to regenerate are key parameters that determine the maintenance of healthy forests (Ordóñez & Duinker, 2012; Wurtzebach & Schultz, 2016). Adequate rainfall is one of the factors that ensure natural regeneration of forests (Khaine et al., 2018). The results show that shortage of rainfall is perceived as impeding the capacity of forests to regenerate naturally. There is an imbalance between the regeneration capacity of forests and exploitation patterns. The findings do not support the view by Garver (2017) that humans reduce exploitation when they realise that their natural resources are ecologically vulnerable. Human exploitation patterns were not being determined by the fact that forests are not regenerating optimally. Instead, the major influence was the people's need to earn a living from forest products. The vulnerability of forests in the area is worsened by the failure of forests to regenerate, which is coupled with high exploitation rates due to community overdependence on forests for livelihoods.

Conclusion

Despite the presence of forest co-management arrangements and community involvement in the conservation of healthy forest ecosystems, forests are threatened by the need to meet food and income security from forest resources, poverty prevalence which emerges in the form of lack of alternative fuel, and overdependence on forests. Climate change is also increasing the vulnerability of forests. Drivers of forest conservation are outweighed by restraining forces. The social-ecological systems which threaten the existence of forests should be addressed in order to improve the health status of the forest ecosystems.

Recommendations

Communities in the three wards in Murehwa District over depend on forests for firewood to burn bricks and cure tobacco. They, however, also have a desire to maintain healthy forests. The Forestry Commission can assist by providing saplings to develop community plantations that will be used as alternative sources of fuelwood and poles. This will alleviate pressure on natural forests. The government and development partners should introduce other ways of cooking that save firewood, such as the use of tsotso stove or jengeta huni/ quedidubo stove. This will ease pressure on forests and increase efficiency. Gardens can be fenced using live fences instead of poles and branches of trees. Agricultural extension officers should teach farmers sustainable agricultural intensification pathways such as improving the fertility of soils already under cultivation by using green manure from forests. Community members will be motivated to conserve forests as a source of manure to improve their soils.

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Chapter 04

Livestock Production and Climate Change: Understanding the Reciprocity and Coping Mechanisms of Smallholder Farmers in a Semi-arid Environment

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Introduction

Agriculture remains the backbone of most developing countries, despite current and anticipated adverse impacts of climate change. Actually, the global demand for agricultural products is estimated to increase by approximately 60% to 70% by 2050, particularly in response to population growth (Silva, 2018). In Sub-Saharan Africa, a shift towards livestock vis-à-vis cropping is expected, as projected increases in temperature and variability in precipitation due to climate change may affect the length of the growing season. Currently, livestock products provide 17% of global kilocalorie consumption and 33% of global protein consumption (Rosegrant, Fernandez & Sinha, 2009). Between 2006 and 2050, it is anticipated that global meat production would have doubled from 258 to 455 million tonnes (Alexandratos & Bruinsma, 2012). On the other hand, crop production is expected to decrease. In Chivi, a semi-arid area in Zimbabwe, crop yield assessments from 1990-2019 show a declining trend, with maize being the most affected as compared to sorghum, pearl millet and finger millet (FEWS, 2019). However, despite better adaptation of animals to climate shocks than crops, regions where livestock is expected to contribute increasingly to food security are the regions identified as the most vulnerable to climate change (FAO, 2016). Global climate change is primarily caused by greenhouse gas (GHG) emissions that cause atmospheric warming (IPCC, 2014). The livestock sector has been documented to contribute 14.5% of these emissions (Grossi et al., 2019). Thus, understanding the nexus between livestock production and climate change is necessary for the sustainability of rural livelihoods.

Animal husbandry is considered the biggest land use that contributes significantly to global warming and climate change (Koneswaran & Nierenberg, 2008). Methane, in particular, is increasing at a rate of 1% per annum to the current status of being the second most important anthropogenic gas causing radiative forcing (Saunois et al., 2020). It is also approximately 28 times as potent as carbon dioxide (CO2) at trapping heat in the atmosphere (Borunda, 2019). Its sources include natural wetlands, biomass burning, and emissions along the value chain of forage production, feed processing and transportation, and enteric fermentation. Ruminants release between 250L to 500L of methane per day through enteric microbial fermentation (Johnson & Johnson, 1995). Contrariwise, climate change affects livestock production through declines in feed quality and quantity, increased prevalence of diseases and disease vectors, heat stress and biodiversity loss (Rojas-Downing et al., 2017). To improve the relationship between livestock production and climate change, we promote climate-smart agriculture which sustainably increases productivity, enhances resilience, reduces/removes greenhouse gases, and enhances achievement of national food security and development goals (FAO, 2013).

Previous scholars have conducted various climate change studies in relation to ruminant production. For instance, Blaxter and Clapperton (1965) developed a model to predict the production of methane based on dry matter intake by ruminants. More recently, Niu et al. (2018) analysed the worldwide database of methane production of lactating cows, and reported similar performance in methane production across regions. However, there is still inadequate information on location-specific livestock production systems, feeds and feeding systems, and quantification of GHG emissions at local levels. The nexus between climate change and livestock is normally generalised at continental and regional levels, or according to agro-ecological zonation. There is also limited knowledge of the coping mechanisms to climate change being employed by small-scale livestock farmers. We hypothesise that such knowledge can result in more effective adaptation and mitigation strategies. It is therefore critically important to be able to precisely determine livestock contribution to GHGs for a given area. Studies of the effects of climate change on rangelands have also been relatively few, regardless of the socio-ecological and economic relevance of rangelands. Thus, the comprehension of the sensitivity of rangelands to current and future climates is also critical for sustainable use of such ecosystem goods and services.

This chapter explores and explains the nexus between livestock production and climate change in semi-arid areas, using Chivi District as a case study. Specifically, we (i) determined type and trends in common livestock production systems (ii) investigated the nexus between climate change and livestock production (iii) identified coping mechanisms being employed to address impacts of climate change in livestock-based livelihoods, and determined factors influencing the choice of these mechanisms (iv) quantified methane gas emissions from different types of livestock, and (v) recommended strategic livestock feeds and feeding systems.

Description of the study area and methodolgy

Study Area

The study was carried out in the semi-arid area of Chivi District in Zimbabwe (Figure 4.1). The district is located between 30° 13' E and 30° 57' E. Mean annual rainfall received in the area ranges from 450 mm to 600 mm, which does not adequately support rain-fed agriculture (Mapanda & Mavengahama, 2011). Therefore, Chivi persistently experiences crop failures and food insecurity. The soils in the district are also inherently infertile chromic luvisols, eutric regosols, ferric luvisols and other coarse-grained granite derivatives. Deepening poverty has resulted in increased deforestation, and overexploitation of other common property resources to supplement household incomes in the area (Bird & Shepherd, 2003).

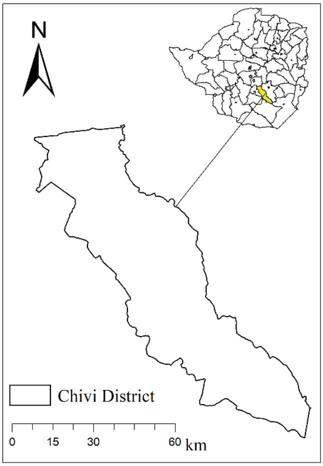

Figure 4.1: Map of Chivi District in Zimbabwe

Data Sources and Collection

Methods

This study has five specific objectives. Thus, a mixed methods research design involving both quantitative and qualitative approaches was used, as outlined in the framework presented in Figure 4.2. Analysis was also undertaken using different methods and procedures depending on data type and objective under examination. Both exploratory and confirmatory data analysis approaches were used.

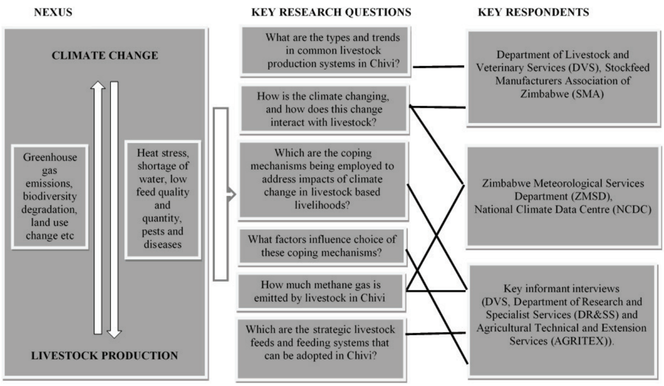

Figure 4.2: Conceptual Framework for the Study on the Nexus between Climate Change and Livestock Production in Chivi District

Situation Analysis

Current and historical data on livestock herds and production systems in the study area was obtained from the Department of Livestock and Veterinary Services (DVS) and private feed manufacturers representing the Stockfeed Manufacturers Association of Zimbabwe (SMA). Furthermore, for a deeper comprehension of climate change related issues, we conducted key informant interviews with nine livestock veterinary and production experts from DVS, the Department of Research and Specialist Services (DR&SS), and Agricultural, Technical and Extension Services (AGRITEX). Both qualitative and quantitative data was analysed in SPSS (IBM SPSS 2012). Time series analysis was done using Mann Kendall test in XLSTART (2020) to determine current livestock production trends from 2015 to 2020. A short period trend analysis was done due to data unavailability. However, this data was supported by using key informant interview data.

Rangeland Productivity

The Normalized Difference Vegetation Index (NDVI) values for the rangelands in the study area were used to represent their productivity. NDVI was calculated as shown in equation 1:

$$NDVI = (NIR - Red) / (NIR + Red) \quad [1]$$

where Red and NIR are the red and near-infrared bands of the electromagnetic spectrum (Jensen, 2000). NDVI values range from −1.0 to 1.0, where higher values are for green vegetation and low values are for water. The Normalized Difference Vegetation Index is the most widely used spectral vegetation index by ecologists and agriculturalists (Fern et al., 2018; Ndungu et al., 2019). Daily MODIS satellite data was used to produce the time-series decadal (ten day) NDVI values for Chivi District from the year 2002 to 2020. To separate rangelands from other forms of land cover, a mask layer was created. A place was deemed to be a rangeland if it was under land cover types such as grasslands, shrublands and woodlands. The median NDVI value for the district rangelands for a particular decad and month were derived and used to show the changes occurring over time. The median NDVI was used because it is resilient to outliers.

Methane Gas Emissions by Livestock

To estimate methane emissions by livestock in Chivi, we used the IPCC approach as recommended by the IPCC in 1996 and further revised in 2006 (IPCC, 2006). Generally, the approach takes into account the following parameters (i) the number of animals, (ii) the type of digestive system, and (iii) the type and amount of feed consumed (Gebetsroither, Strebl & Orthofer, 2002). Calculations can be done at three levels – Tier I, Tier II and Tier III, based on the availability of data. In this study, we employed the Tier I method, which uses default emission factors combined with the total number of livestock in the country. This method has been successfully used before (Schueler et al., 2018).

Trends in Climatic Indicators

Rainfall and temperature data was obtained from weather stations close to Chivi District which are run by the Zimbabwe Meteorological Services Department (ZMSD). To validate and check the accuracy of the data, we regressed it with data obtained from the National Climate Data Centre (NCDC) which is managed under National Oceanic and Atmospheric Administration (NOAA) programmes for preserving, monitoring and provision of climate and historical weather data (www.ncdc.noaa.gov). 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 4.3 shows the regression results of ZMSD by NCDC data.

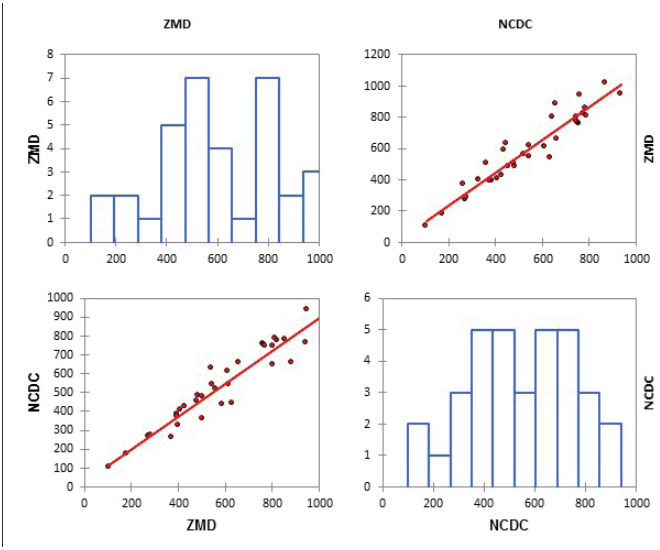

Figure 4.3: Relationship between NCDC and ZMD Meteorological Records

The strong positive relationship between the two data sets from different sources confirmed the data sets used as an accurate record of meteorological variables in the study area. Table 4.1 shows the climatic variables that were analysed in this study.

Table 4.1: 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

Data Analysis

Normality Tests

Long-term meteorological data, which comprised the time series data, was tested using the Kolmogorov-Smirnov test to ascertain whether or not it deviates from a normal distribution. This helped in determining whether the data satisfies assumptions of parametric or non-parametric statistical analysis methods (Chapungu et al., 2020). 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

Meteorological data was 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 & Rao, 1998). Its detection would require the data to be pre-whitened. 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 & Rao, 1998). The ARIMA model performs time series forecasting and smoothening and projects 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 (Chapungu, 2018). 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. The MK test is a non-parametric method commonly employed to detect monotonic trends in a series of environmental, climate or hydrological data. The test is simple, robust, can cope with missing values and seasonality, and values below the detection limit (Hirsch et al., 1993; Dietz & Kileen, 1981). An add-in of Microsoft Excel, XLSTAT 2020, was used to carry out this test due to its ability to remove the effect of auto-correlations.

Using the Mann Kendall test, the null hypothesis, H0, is that there is no trend in the series. Thus, the data comes from a population with independent realisations and is identically distributed. The alternative hypothesis, H1, 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 2:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn\,(Xj - Xk) \qquad [1]$$

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

Results

Situation Analysis

Importance of Livestock

We observed that livestock farming is important for smallholder farmers in Chivi. Farmers in this area keep different types of livestock that include cattle (beef and dairy), sheep, goats, donkeys, pigs, poultry (indigenous chickens, ducks, turkeys, guinea fowls and broilers), and rabbits. Livestock production primarily benefits the farmers through the provision of meat, milk, eggs and livestock by-products. It is also a source of household income, manure and draught power. Farmers use livestock in barter trade, and as a form of savings. Cattle, in particular, are a measure of wealth. Extensive production systems are the common practices of animal husbandry. Supplementary feeding is mainly offered during the dry season.

Livestock Production Trend in Chivi District

Key informant interviews revealed that over the past 30 years livestock production has increased in Chivi. Current cattle production trends in the area from 2015 to 2020 are illustrated in Figure 4.4. Generally, there has been an increase in cattle numbers from 109 890 in 2015 to 113 924 in 2020. A five-year time series analysis revealed a significant increase ($P = 0.01$, $\alpha=0.05$) in cows, calves and heifers during this period. The number of cows, heifers and calves increased by 12%, 16% and 9 %, respectively. The number of bulls also changed significantly ($P<0.05$), with a decline from 94 000 to 85 000 over the five-year period.

The five-year time series analysis also showed significant changes ($P<0.05$) in the number of pigs, donkeys and sheep (Figure 4.5). The number of pigs significantly decreased ($P = 0.01$) by 12% from 2304 in 2016 to 2017 pigs in 2018, and then subsequently rose by 24% to a peak of 2500 in 2020. Similarly, the number of sheep significantly decreased ($P = 0.01$) by 33% from 8349 to 5600, before increasing by 13% to a peak of 6317 in 2020. However, goat populations did not vary significantly ($P>0.05$). The number of poultry and donkeys decreased by 12% and 27%, respectively (Figure 4.5).

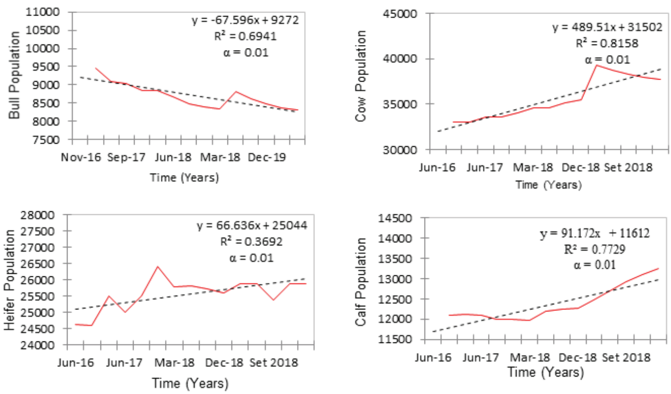

Figure 4.4: Five-year Cattle Production Trend in Chivi District, Masvingo

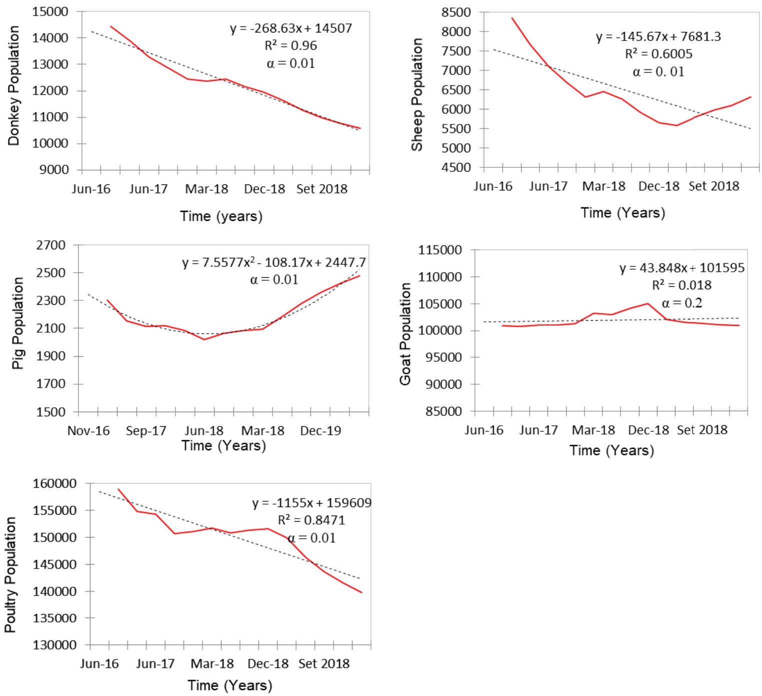

Figure 4.5: Five-year Livestock Production Trends in Chivi District, Masvingo

Indicators of Climate Change in Chivi

The key informants also highlighted that Chivi has been experiencing climate change in the past 30 years, with the major indicators being increases in the frequency of mid-season dry spells and drought events, erratic and unreliable rainfall with a decreasing trend in quantity, and increases in temperature. Table 2 demonstrates the trends in rainfall and temperature in Chivi over the past 40 years. The onset of the rains has also been noted to have shifted from mid-October to December, resulting in a shorter growing season that reduces the sustainability of crop production.

Climate Change Trends in Chivi District

The 40-year temperature and rainfall data shows that climate change is occurring in Masvingo Province and, consequently, in Chivi District. Table 4.2 shows data and descriptions of trends for seven climatic variables.

Table 4.2: Bioclimatic Variables Explaining Climate Change in Chivi District

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

Seven 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 maximum seasonal precipitation (SMP), show a declining trend. This shows that in general, there is a decline in the amount of rainfall received in the study area over time. Table 4.3 summarises how these changes have impacted livestock production in Chivi, according to key informants and other secondary sources in the study.

Table 4.3: Impact of Climate Change on Livestock and Livestock-based Livelihoods

Parameter	Impact
Feeds and Feeding Systems	Generally, there has been a decrease in both the quantity and quality of feeds due to climate change. With increases in mid-season dry spells and the frequency of droughts, rangeland productivity has been on the decline. Consequently, some farmers have shifted from purely extensive production systems to supplementary feeding, particularly in the dry season. A few others are taking up pen fattening to improve condition of slaughter animals. A change in feeding behaviour has also been observed, with cattle, in specific, adapting to low feed availability and quality by increasing browsing tendencies. Effects of poor nutrition on libido of breeding stock, especially bulls, has been affecting conception rates of animals. Goats have not been severely affected by feed shortages, and their population shows a flat trend. The need for supplementary feeding has increased competition between humans and livestock for maize, soya bean and other food crops that are also sources of animal feeds.

Water	Decreases in rains and the subsequent low underground water culminate in early drying up of water bodies. Thus, as observed, water availability is reduced especially in the dry season, with negative implications on animal health and reproduction, mostly.
Heat Stress	Increases in temperature and heat stress adversely affect the oestrus cycle, resulting in delays in coming on heat. Most cattle deaths are caused by heat stress too. Whilst indigenous cattle breeds have shown considerable resilience, exotic breeds such as the Brahman and Friesland have been the most affected. Unlike cattle, goats have also shown considerable resilience to climate change related shocks.
Livestock Health	Increases in temperature and drought events have resulted in an increase in the frequency and severity of certain livestock diseases and disease vectors. For instance, lumpy skin and theileriosis outbreaks now occur throughout the year, yet they were normally more prevalent during the summer and in the month of January, respectively.
Biodiversity	Rangeland species composition and structure has changed, with an increase in bush encroachment, and invasive and unpalatable grass species. Other species have also been reported to be disappearing from the district.
Indirect impacts	In recent years, there have been inconsistencies in government support and intervention in livestock health management, in infrastructural development, and dipping and vaccination programmes. Funding from both the government and NGOs is being channelled more towards food aid and human health programmes, especially to address malnutrition and food insecurity due to climate change and variability.

Impact of Climate Change on Rangeland Productivity

Climate change has also negatively impacted rangeland productivity, mainly through its effect on temperature and rainfall. Figure 4.6 shows the long-term decadal NDVI values for rangelands in Chivi. We observe increases in the productivity of the rangelands from October (the beginning of the rainfall season) to peak values in the decads of April. From May to September (the dry season), productivity levels will be on the decline, and they reach the lowest levels in the month of September

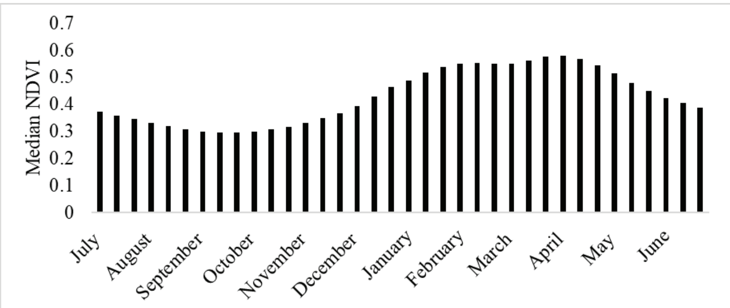

Figure 4.6: Median NDVI Chivi Rangelands 2003-2019 (Source: Authors, derived from MODIS satellite)

Figure 4.7 also shows that except for the months of October and May that show a slight increase in productivity within rangelands, the period from 2002 to 2020 shows declining productivity in Chivi rangelands. Even during the peak of the rainfall season in months like December and January, the long-term trend shows a decline in the vegetation production.

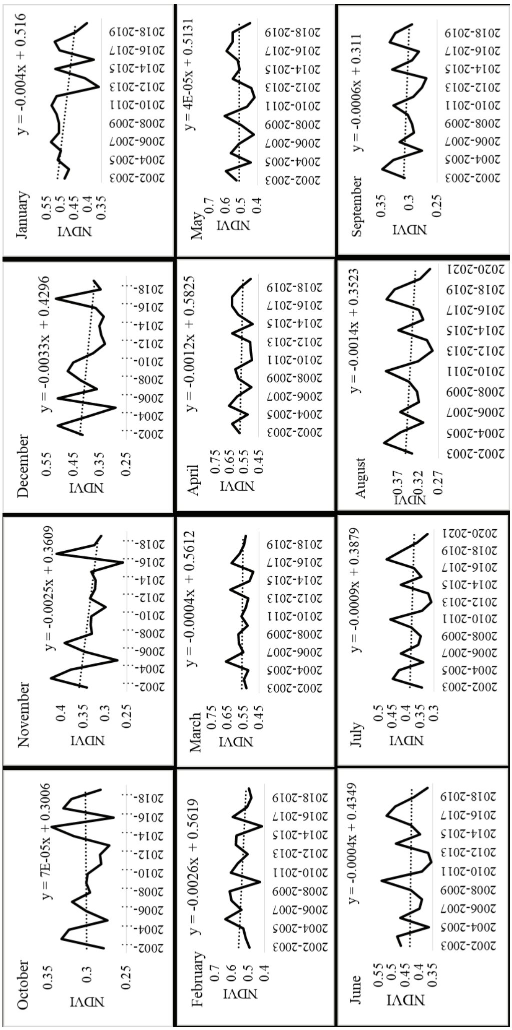

Figure 4.7: Monthly NDVI Values for Rangelands in Chivi District from 2002-2020

Impact of Livestock on Climate Change

The major contribution of livestock to climate change highlighted by the key informants was through GHG emissions from manure, feed production and environmental pollution, as well as overgrazing and biodiversity destruction. Land degradation was noted to be on the rise due to the expansion of agricultural land for crop and forage production, as well as the establishment of holding pens and overnight kraals to improve livestock infrastructure for protection in extreme weather conditions. Increase in microbial resistance, and the high cost of conventional drugs, have necessitated shifts towards the use of ethnomedicinal plants in livestock health management. However, biodiversity conservation is affected by overutilisation and mismanagement of these ethnomedicinal plants, which has been observed in some areas in the district due to their multiple-use nature. Manure, another source of methane, accumulates in the cattle kraals for approximately 12 months before it is used as organic fertilisers for crop production. Apart from manure, forage production also uses inorganic fertilisers that contribute to GHG emissions.

Estimation of Methane Gas by Livestock in Chivi District

The annual accumulation of the methane emissions for Chivi District from March 2015 up to March 2020 reveals figures ranging from 3.97 Gg in 2015 to 4.08 Gg in 2020 (Figure 4.8). Table 4.4 shows the emissions for Chivi District and the national emissions from different types of livestock. Chivi emissions represent an average of 11.11% of the entire enteric emissions in Masvingo Province where Chivi District is located, and approximately 2.05 % of the national emissions. In Chivi, cattle have the largest contribution of 86.4%, followed by goats at 12.63%.

Table 4.4: Average Enteric Methane Emissions from 2015 to 2020 in Chivi District

Animal	Chivi Emissions (Gg CH4 per year)	National Emissions (Gg CH4 per year)
Total Cattle	3.42	168.8
Sheep	0.037	2.6
Goat	0.5	21.8
Pig	0.003	0.23
Summation	3.96	193.4

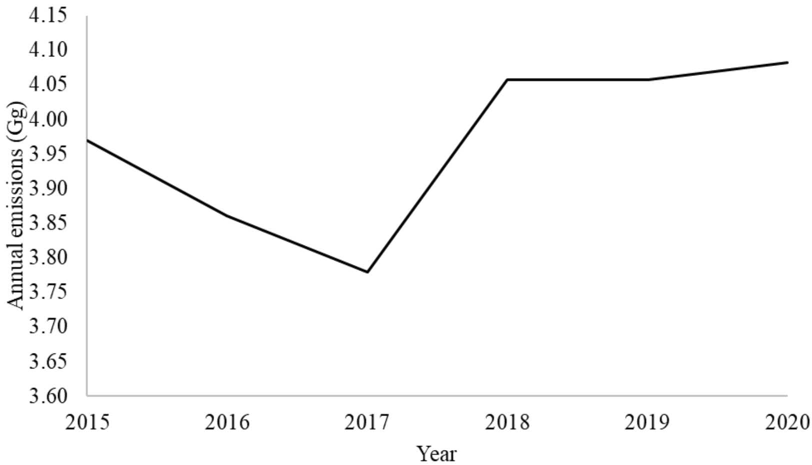

Figure 4.8: Enteric Emission from Livestock Production in the Chivi District from 2015 to 2020

Coping Mechanisms by Livestock Farmers to Combat the Effects of Climate Change

Livestock farmers in Chivi have developed mechanisms to cope with the effects of climate change. As highlighted by the key informants, these coping mechanisms seek to provide feed, water, and veterinary requirements, as outlined in Table 4.5.

Table 4.5: Coping Mechanisms by Livestock Farmers in Chivi, Zimbabwe

Coping Mechanism	Factor Influencing the Choice of Mechanism
Use of Ethnoveterinary Plants	There is knowledge of indigenous knowledge systems pertaining to ethnoveterinary medicines in Chivi. The district has a wide diversity of ethnobotanical plants that are used as medicines in livestock health management. These medicines are environment-friendly, locally-available and easy to prepare.
Cattle Relocation	Some farmers relocate their cattle, especially during the dry season, to areas with better pastures, for instance, Tokwe Mukosi Basin. This ensures feed availability. However, these areas are limited.
Supplementary Feeding	There is also a wide feed resource base that includes cereal and leguminous crop residues after harvest. These can be used to supplement animal feeds during times of feed scarcity. Appropriate technologies for producing these feeds have been developed at government research institutes, and have been cascaded down to farmers over the years.

Destocking	Destocking is normally done as an emergency response to droughts in order to reduce potential loss of animals. Destocking can be for home consumption or income generation. Money generated is normally used for purchasing feeds and vaccines to save the remaining animals.
Reducing the Frequency of Watering Animals	As the dry season progresses, farmers reduce the frequency of watering their livestock to once in two days, as the distance to the few remaining water sources is normally very long.
Readoption of Indigenous Livestock Breeds	Farmers are reintroducing indigenous breeds into their herds as these breeds are more adaptable to harsh climatic conditions than the exotics. Breeding stock is available through government initiatives of conservation of indigenous livestock breeds.
Youth Migration and Rural-Urban Migration	There is an increase in youth migration and rural-urban migration in search of other remittances as potential substitutes for farm income.

Feeding Strategies to Combat the Effects of Climate Change on Livestock

Climate change has negatively affected rangeland productivity in Chivi, yet these rangelands are the main source of livestock feeds. Therefore, to improve the feed situation in the study area, we recommend strategic feeds and feeding systems presented in Table 4.6. These strategies were developed with the following aims: achieving effective dry season feeding, thereby improving ovarian cycling, reducing post-partum anoestrus, silent heats and long birth intervals; increasing milk yield; reducing calf and kid mortality rates; improving weaning weights, and reducing poverty deaths. The feasibility of adopting these strategies is also presented in Table 6.

Table 4.6: Recommended Feeding Strategies to Combat the Effects of Climate Change on Livestock

Strategy	Feasibility Factor
Use of Cactus	Cactus is adapted to semi-arid areas. It is easy to establish; it colonises vast areas and has high water content. Additionally, cactus is suitable for making silages for livestock feeding. Information on possible benefits of utilising the plant is available.
Fodder Banks	Fodder banks can be established at the household or community level, or in small groups. The production process does not require sophisticated machineries such as tractors, hay bailers and wind rollers. In addition, pasture seed is readily available from government livestock research institutions. Surplus hay produced can also be sold to other farmers for income generation. Land for pasture establishment is available as semi-arid regions are less suitable for crop production.

Browse Species	There is a variety of browse species in Chivi, as well as traditional ecological knowledge for the preparation of the bush meal, and use of root tubers or pods in livestock feeds. Other modern technologies can also be used.
Velvet Bean	Velvet bean does not require a lot of water and can be grown successfully within semi-arid areas. It also produces hay which can be fed to livestock. There is a lot of documentation on how velvet bean can be utilised for livestock, including in Total Mixed Rations (TMRs) to replace bought-in supplementary feeds.
Rangeland Rehabilitation	There are many affordable ways of improving rangelands at the community level, which include grazing rehabilitation, veld reinforcement, and control of bush encroachment and invasive species.
Urea Treatment of Stover	Knowledge on urea treatment of stover for ruminant feeding is available. Chivi District receives low rainfall, hence when there is crop failure the stover can still be urea treated to benefit ruminant feeding.
Indigenous Grass-based Silage	Due to erratic, low rainfall received in Chivi, grass can be harvested during the growing season for ensilage.

Discussion

From our observations, the multiple roles of livestock in Chivi indicate the significance of livestock-based livelihoods in semi-arid landscapes. These areas are characterised by low rainfall with high spatial and temporal variability that often increases the probability of severe droughts (Snyder & Tartowski, 2006). Congruent to our findings, previous studies have also documented many socio-political and economic uses of livestock in semi-arid areas. For instance, livestock produces manure which is increasingly becoming important for sustainable agriculture, mainly as a source of organic fertiliser (Nyalemegbe, Oteng & Asuming-Brempong, 2009; Zafar et al., 2011). Livestock production also ensures food and nutritional security as animals are more adapted to marginal areas than crops. Therefore, livestock production reduces risks and creates a buffer from the effects of climate change.

Our results demonstrate climate change in Chivi in the past 30 years. Key informants reported increases in mid-season spells and extreme weather events as some of the major indicators of climate change. These observations are supported by decreasing trends in rainfall and increasing temperature observed from actual climatic data collected from 1974 to 2014. Such observations have also been made in surrounding countries (Ziervogel et al., 2014; Artura & Hilhorst, 2012). However, this is not surprising as the IPCC (2014) has predicted that global average surface temperature is likely to increase between 0.3º C and 4.8º C by 2050. Climate change impacts livestock through reductions in feed quality and quantity, increased prevalence of diseases and disease vectors, decreased water availability and increased heat stress, among other factors (Rojas-Downing et al., 2017). However, with increased crop failures, farmers may switch and invest more in livestock; hence the increases in the total number of animals observed in this study. Consistent with this finding, Murungweni et al. (2012) also highlight that farmers in the South-East Lowveld of Zimbabwe, where Chivi is located, keep large numbers of livestock as a hedge against drought. We also acknowledge that livestock, being domesticated animals, is not only affected by biophysical 'climatic factors', but also reflects farmers' investment decisions. An interesting contrast is a declining trend in donkey population (an animal well known for its resilience to drought) and the peaking pig population. For economic reasons, farmers could be investing more in pig production than donkey production. The increases in livestock numbers can also be attributed to autonomous adaptation by households to frequent and severe droughts that affect crop production. Moreover, the increases are a reflection of livestock recovery plans and other strategies by government and NGOs in the livestock industry to increase the national herd. Such strategies are normally targeted at improving the livestock health system, as well as the genetic and feed resources, consequently increasing production.

Declines in rangeland productivity reported in this study are worrying as, coupled by the projected increases in the human population in semi-arid areas, rangelands will not only have pressure to provide livestock feed, but to also deliver other ecosystem goods and services. We report rangeland deterioration in terms of changes in vegetation composition and structure, and the proliferation of undesirable and invasive plants in our study. Our results also demonstrate that livestock contributes towards climate change. This is reflected in our total enteric emissions, estimated at 193.4 Gg per year. This figure is within the range quoted by other researchers in Zimbabwe, for example, Svinurai et al. (2017) who demonstrated the effect of livestock on climate change by showing declines in methane emissions after the fast-track land reform programme of 2000 when most of the commercial farmer removed their livestock because of the changing land tenure system in Zimbabwe. Overall, we recommend scale-specific, and multidisciplinary research in climate change adaptation and mitigation strategies to improve the nexus between livestock production and climate change.

Conclusion

Our study shows that there are different types of livestock in Chivi, mostly reared under extensive production systems. These have multiple uses ranging from food provision, the supply of manure, draught power and income generation. We observed changes in the climate system in the past 40 years, with adverse impacts on livestock production. These impacts, although not reflected in the general increasing trend of production, negatively affect rangeland productivity, livestock nutrition and reproduction. We also found out a reciprocal link between climate change and livestock production. For instance, methane emissions from livestock feed production and processing, and the use of manure, also affect climate change. Our estimates of methane emissions from livestock in Chivi District are 11.11% and 2.05% of the provincial and national enteric emissions, respectively, an indication of the potential contribution of livestock to GHGs. Farmers in Chivi have developed different coping mechanisms to address impacts of climate change on livestock production, such as reintroducing indigenous breeds, and cattle translocation during droughts. These mechanisms are influenced by factors such as resource availability, the prevailing economic situation and indigenous knowledge systems. To add to these coping mechanisms, we recommend the use of cactus, velvet bean, browse species and other strategies appropriate for sustainable livestock production in semi-arid regions.

Recommendations

Our study is unique in that it evaluates the nexus between climate change and livestock production at a local scale, unlike most studies which are mainly done at national or global levels. To improve feed availability, we recommend the upscaling of already existing feed production technologies such as urea treatment and ensilage, in addition to the development of fodder banks, and the use of cactus, velvet bean and browse species, among other locally-available resources presented in Table 6. We also recommend the formation of farmer-based management committees to facilitate effective rangeland management and utilisation. This addresses challenges of management of common-pool resources such as rangelands. Regarding GHG quantifications, we recommend further characterisation of local area dynamics in order to develop, not only country-specific emission factors, but also models which capture improved profiles of livestock production systems in Zimbabwe.

Further research on GHG emissions in Zimbabwe will also enable the use of more reliable methods such as the Tier III, instead of default emission factors, in estimating the contribution of the livestock production system to climate change. Lastly, we would like to acknowledge limitations that may be presented by the use of a short, five-year period to determine trends in livestock production. This was due to data unavailability. However, results from the trend analysis were consistent with key informant interview data. Nevertheless, we recommend longer-term trend analysis in future research.

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Chapter **05**

The Effects of Climate Change on Food Security and Response Strategies: A Case of Smallholder Farmers in Gokwe South District, Zimbabwe

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Introduction

Climate change is one of the current topical issues that are always on the agenda whenever nations meet to discuss development issues hampering economic progress for their economies. According to Bene et al. (2014), with major long-term changes in weather and rainfall patterns, climate change impact on livelihoods among developing countries is likely to be felt. This calls for the availability of climate change adaptation practices to promote food security among smallholder farmers. Unless farmers adapt, the effects of climate change will continue to threaten their food security.

Climate change is likely to affect rural livelihoods and become a multiplier of poverty whereby the poor become poorer (Hallegatte et al., 2016). Sub-Saharan Africa is the most vulnerable region in the world to global climate change trends due to increased evapotranspiration and changing rainfall patterns, lack of adequate adaptation capacity and common occurrences of droughts (Muzawazi et al., 2017). It should not be overlooked that vulnerability is also traceable to macro policies and practices, including corruption in the region.

The substantial effects of climate shocks on humanity are being felt through droughts, famine, extreme weather conditions, floods, water crisis and health-related risks. According to the Swinkels et al. (2019), in 2011-2012, about 2.8 million Zimbabweans were extremely poor, with 91% of them residing in rural areas where they rely on climate-sensitive agriculture. This increases their vulnerability levels due to unsustainable climate-centred livelihoods, leaving 69.1% of households food insecure and requiring urgent cereal assistance, with 98% not well equipped to combat it (ZimVAC, 2019).

According to Bene et al. (2014), both climatic and non-climate-related shocks can force households to engage in asset-depleting coping strategies. The depreciation of local currency in Zimbabwe is forcing people to venture into barter trade within their communities. Destocking is also used as a strategy of coping with the effects of climate change amongst smallholder farmers. However, there is a lot of resistance among local communities on destocking since livestock is perceived as a source of wealth and prestige, and there are also cultural-significant meanings attached to its availability. As a result, the value from the destocking process is converted into assets or other valuable items. The objective of this study was to assess the effects of climate change on food security among smallholder farmers in Gokwe South District, as well as to find out adopted responses to the impact of climate in addressing food security.

Description of the study area and methodology

Study Area

This study was conducted in Gokwe South District, which is situated in the Midlands Province of Zimbabwe. Geographically, the district borders with Sanyati and Gokwe North to the East, Kwekwe and Nkayi to the south, Binga and Lupane to the west as well as some part of Binga and Gokwe North to the north (Figure 5.1).

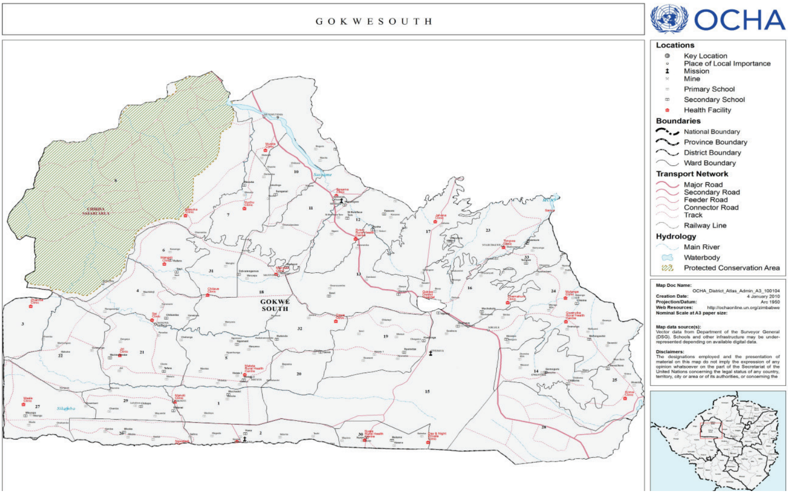

Figure 5.1: Map of Gokwe South District

Source: United Nations Office for the Coordination of Humanitarian Affairs (2008:01).

According to Tasaranago and Salawu (2013), Gokwe South people keep small herds of cattle of about five to eight, due to a lack of grazing land which they sell when in urgent need of cash. Before the colonial era, the area was sparsely populated with only the Shangwe (a Shona tribe) people in the Zambezi Valley (Nyambara, 2002). This was because of the unfavourable temperatures as well as the fact that the area was tsetse and mosquito-infested. The native inhabitants had been expelled from areas around Harare, Kwekwe and Bulawayo after the Second World War, and they resettled in Gokwe (Ranger, 1985). However, the elimination of tsetse later on also allowed the settling of more people in the area. The Madheruka ethnic group came in the 1960s and started cotton cultivation. They disparaged the indigenous Shangwe as "primitive", "backward" and "resistant" to change, while colonial officials regarded the immigrants as the embodiment of "modernisation" and as model farmers to be emulated (Ranger, 1985). Due to severe changes in the climate, as well as political dynamics, historical injustices and economic strains, Gokwe South District has seen various Non-Governmental Organisations (NGOs) trying to bring relief to its people.

Research methodology

This study was informed by pragmatism whereby the worldview amongst the research participants arises out of actions, experiences and consequences rather than predetermined conditions (Cresswell, 2014). This was the best approach for the study, which assists in coming up with viable climate change adaptation strategies among the smallholder farmers, as it produces rich evidence-based data. Convergent parallel mixed methods were used for this study. Cresswell (2014) confirms that the use of convergent parallel mixed methods designs allows researchers to merge both qualitative and quantitative data for a comprehensive analysis of the presenting problems.

Study Site Selection and Sampling Methods

Gokwe South District is reflective of rural communities that are being affected by climate change issues. The unit of analysis for the study was the smallholder farmer. The target population includes all the 84 000 households in Gokwe South District (Zimbabwe Food Poverty Atlas, 2016). Based on the Slovin's Sample Size Calculator, with the use of random samples, the minimum sample size required for a population of 84 000 households is 383, with 95% confidence levels and 5% margin error.

Cluster sampling was used in selecting the 1000 households. The researchers clustered the target population according to their constituencies — Gokwe Mapfungautsi, Gokwe Central, Gokwe Kana, Gokwe Sessame and Gokwe Sengwa. Simple random assignment was used in selecting respondents for the questionnaires' survey. Purposive sampling was also used to identify key informants to ensure that only those individuals that were deemed to have information on the effects of climate change and adaptation strategies in the study area were engaged. As such, key informants for this study were drawn from the office of the District Administrator (DA) (renamed District Development Coordinator, DDC), District Agritex Office, Department of Social Development (DSD), chiefs, MPs, councillors and other development partners.

In terms of the administration process, the questionnaires were distributed among 1000 households. A total of 15 smallholder farmers randomly selected from the clusters were engaged for the indepth interviews. In selecting 20 members for two focus group discussions (FGD), the researchers used convenience sampling to avoid interfering with people's normal activities and capitalising on scheduled programmes.

Data Analysis Procedures

Statistical Packages for Social Sciences (SPSS) Version 26 was used to come up with descriptive statistics. Qualitative data was used to explain trends emerging from descriptive statistics.

Ethical Considerations

The researchers were aware of poverty levels among respondents as well as power relations with smallholder farmers. The researchers explained to them that there were no risks associated with their non-participation or voluntary withdrawal. The researchers also got clearance to conduct the study from the District Development Coordinator (DDC) of Gokwe South. Written informed consent was also obtained from all the respondents and participants before their participation in the study.

Results and Discussion: Socio-economic Demographic Information

The socio-economic and demographic characteristics of respondents focused more on their sex, age range, level of education and the monthly levels of income. Table 5.1 gives a presentation of the socio-economic and demographic characteristics of the respondents.

Table 5.1: Socio-economic Demographic Information for the Study Respondents

Variable	Percent
% of female	51.70
% of male	48.30
% aged 0-17	1.52
% aged between 18 and 35	20.00
% aged between 36 and 53	51.46
% aged between 54 and 71	20.70
% aged between 72 and 89	5.50

% aged between 90 and 107	0.82
% with no education	3.51
% with primary education	21.17
% with secondary education	67.37
% with tertiary education	7.95
% earning 100-2000 per month	77.5
% earning more than 2000 per month	22.5

The study findings show that 51.70% of the study respondents were females and 51.46% of the respondents were between the ages of 36 years and 53 years, with few incidences of child-headed families. This distribution pointed to a scenario whereby 72% of the respondents are still economically active, while a few are elderly people and children. The economically active respondents are expected to contribute immensely towards household food security. The results also show that 67.37% of the respondents had a secondary education qualification, and 3.51% had no education. The illiteracy rate has been noted to be one of the reasons for non-completion of other questionnaires distributed.

In terms of the level of incomes, the study findings show that 77.5% of the respondents were earning an average monthly income of ZWL$500 and ZWL$2000 per annum. Using the interbank exchange rate of ZWL$81.85 for 1USD, the range translates to USD6.11 and 24.43 respectively. It therefore means all the households are below the Poverty Datum Line of USD1.25 per person per day. According to key informants, one of the reasons for the low incomes relates to lack of formal employment as well as low selling prices for agricultural produce by smallholder farmers.

Effects of Climate Change

Studies on climate change impact have highlighted a plethora of challenges that are associated with climate change. From this study, the decline in harvests or agricultural outputs over the past 10 years, and the changes in food consumption, emerged as the major effects of climate change among Gokwe smallholder farmers.

Perceived Impact of Climate Change on Harvests

One of the effects of climate change is reduced harvests due to droughts which stress crops. Farmers were asked if they had experienced a decline in the yield of their cereal crop over the last 10 years due to climate change. Figure 5.2 presents the distribution of the responses of the smallholder farmers in Gokwe South on the effects of climate challenge on crop production over the last 10 years.

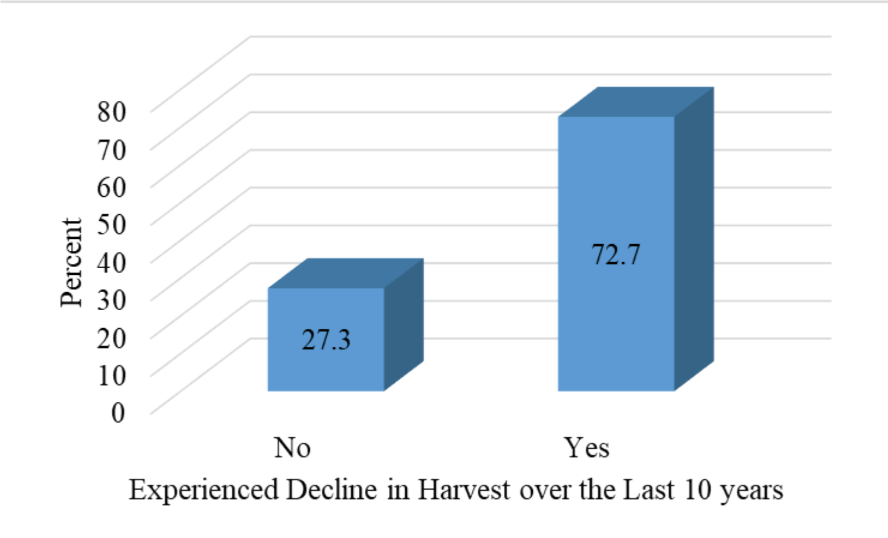

Figure 5.2: Distribution of households that reported change in yield over the last 10 years

Results presented in Figure 5.2 show that 72.7% of the respondents confirmed that they had experienced a decline in harvest over the past 10 years. The key informants reported that rain seasons had changed, rainfall had decreased, temperatures had increased, and droughts had persisted. Accordingly, smallholder farmers have lost hope in cereal crop production as they suffered many losses due to erratic rainfall patterns, leading to decreased yields. This has negatively impacted the food security of smallholder farmers. To make matters worse, households of smallholder farmers do rarely have reliable sources of income to buy adequate food for all members. Table 1 clearly shows that 77.5% of the smallholder farmers earn between ZWL$100 and ZWL$2000, which worsens their capacity to secure food for their households. This leaves them in high poverty levels and more vulnerable as they fail to ensure food security amongst themselves.

Change in Food Consumption

Climate change affects food availability. One of the effects that this study discovered relates to the changes in the number of meals taken per day among respondents. The changes in eating habits can be considered both an effect of climate change as well as a coping mechanism to the effects of climate change. People would always opt to reduce the number of meals when faced with food shortages. Respondents were asked if they had reduced the number of meals consumed per day in response to food shortages caused by climate change. Results presented in Figure 5.3 show the distribution of answers to the question.

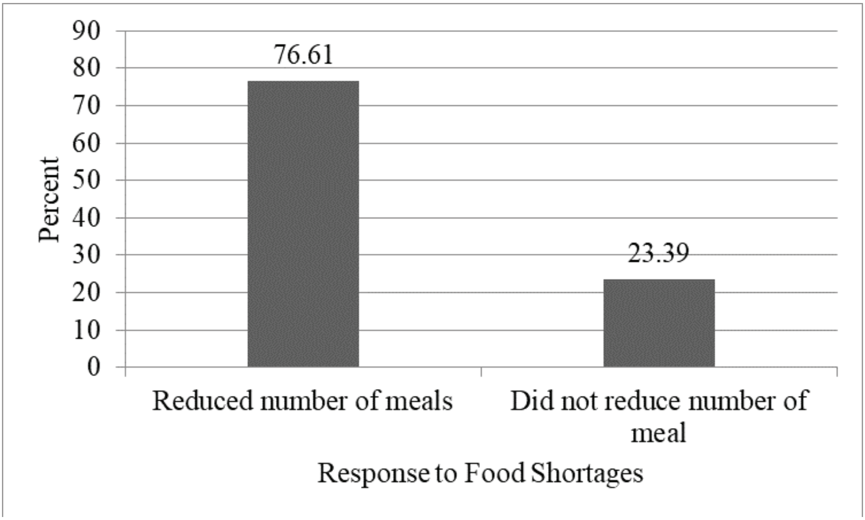

Figure 5.3: Distribution of households that adopted difference response strategies

Results in Figure 5.3 show that 76.61% of the respondents reduced the number of meals that they were taking per day. According to the ZimVAC report (2020), in the Midlands Province, a total of 20.3% of households showed poor food consumption. This exposes them to food insecurity and malnutrition as they fail to purchase adequate and dietary foods due to high financial poverty levels (ZimVAC, 2020). The reduction in the number of meals that are eaten by a household per day has negative effects on health, as household members fail to get a balanced diet required for their health.

Responses to Climate Change

The study also sought to establish climate change adaptation and coping mechanisms that the affected household use when facing food insecurity. This is very much pertinent considering the devastating effects of climate change in

Gokwe. The study sought to establish the extent to which farmers are self-insuring and also using government programmes to ensure that they are food secure.

Financial Support

Financial support is of uttermost importance in ensuring a food secure household. With adequate funds available, it is easy for a household to buy food of their choice from shops and individuals who have cereal for sale. Smallholder farmers rely on various sources for financial support to secure food for household members. However, in the event of no stable financial support, it is difficult to promote food security in a household. Smallholder farmers were asked where they get financial support to secure food for their households in the face of climate change-induced food security. Figure 5.4 shows the distribution of smallholder farmers who sought financial support from different sources.

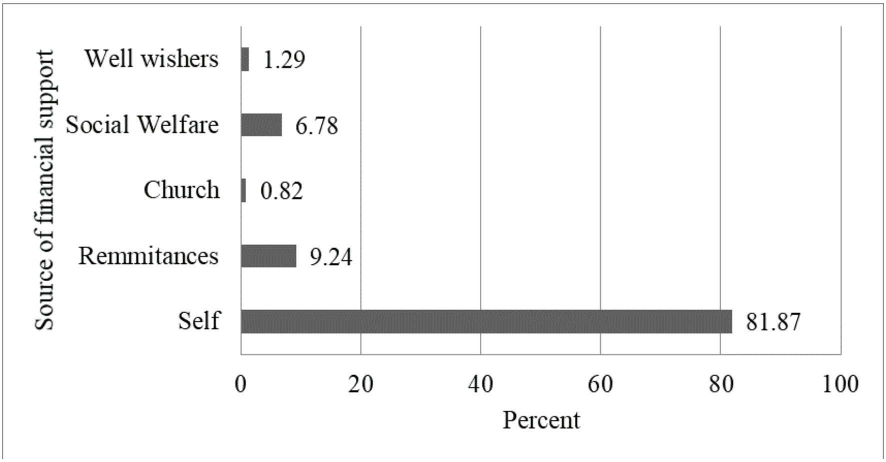

Figure 5.4: Distribution of households receiving financial support from different sources

The results in Figure 5.4 show that 9.24% of the households relied on remittances for food availability. About 6.78% of the respondents affected by climate change got food through social welfare assistance. Also, a total of 1.29% and 0.82% relied on church support and well-wishers for food assistance, respectively. The results in Figure 5.4 show that 81.87% of the respondents relied on their own sources of income to buy food. This presents a challenge to about 27% of the economically inactive (see Table 5.1) households who are either child-headed or elderly-headed.

Sources of Household Income

Smallholder farmers who relied on themselves for financial support were asked what kind income-generating venture they were engaged in. The distribution of households that engage in different income sources are presented in Figure 5.5. The income sources range from agriculture, artisanal mining, formal employment, informal trade, pensions and others.

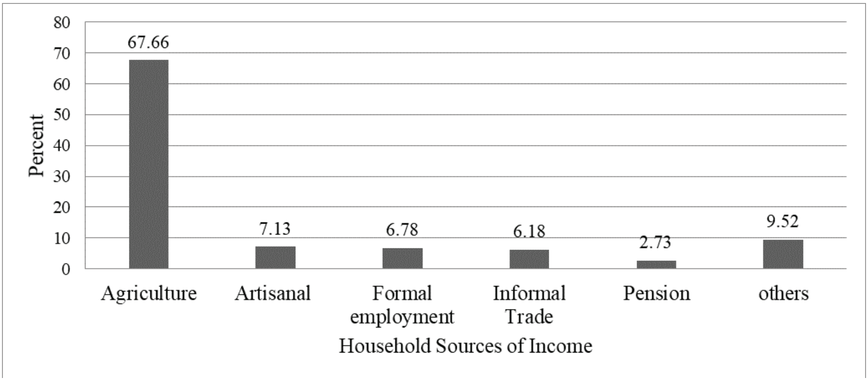

Figure 5.5: Distribution of households generating money from different activities

Results in Figure 5.5 show that agriculture is the dominant source of income for 67.66% of the households. The indepth interviews revealed that smallholder farmers would participate in income-generating from agro-based activities. Key informants confirmed that smallholder farmers promote their own food security through selling crops, livestock and horticultural products. These farmers then use the income from these practices to buy food for their households. Only a few households use their pension to buy food.

The study findings show that smallholder farmers face financial challenges in securing food for all household members. This is worsened by their already vulnerable financial standing as reflected by the monthly earnings reflected in Table 5.1, which shows that all the households are below the poverty datum line. According to the ZimVAC report (2020), nationally, 34.9% of the rural population relies on casual labour as a source of income. This, therefore, exposes them to food insecurity as they may not afford to buy food in times of need, and social safety nets are not well developed (ZimVAC, 2020).

Participation in Government Food Security Programmes

Participation in government food security programmes is one of the climate change adaptation strategies that some Gokwe South smallholder farmers considered in responding to climate change effects. Smallholder farmers were asked if they were participating in the Food-for-Work Programme. Results in Figure 5.6 show the distribution of households that participated and those that did not participate in food for work programmes as a coping strategy against food shortages.

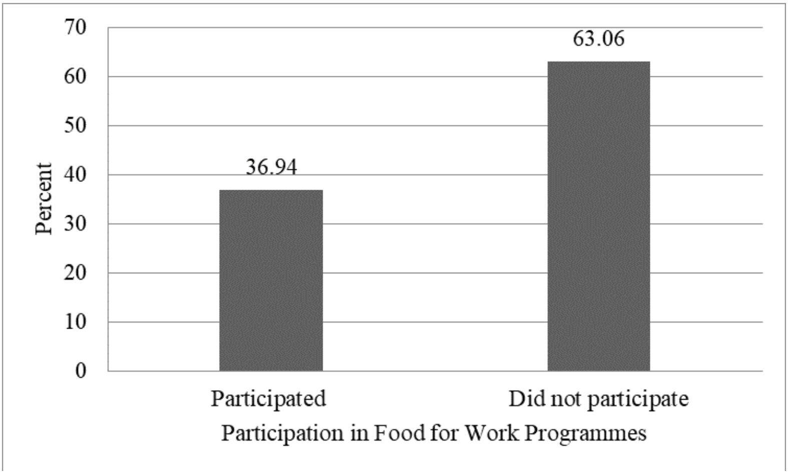

Figure 5.6: Distribution of respondents either participating or not in in Food-for-Work Programme

Results in Figure 5.6 shows that 36.94% of the households participated in food-for-work programmes. The programme is considered one of the strategies for promoting food security among vulnerable households. According to key informants, vulnerable households engaged in reclaiming roads in exchange for cereals. Key informants reported that the participation in the Food-for-Work Programme is minimal among smallholder farmers as the Department of Social Development does not have adequate maize grain for the activity. This reduces the capacity of smallholder farmers to address food insecurity among their household members.

Participation in Crop-yield Enhancing Strategies

A number of government programmes are being implemented to improve food security. The smallholder farmers in Gokwe South were asked if they participated in crop yield-enhancing strategies. The results are presented in Figure 5.7.

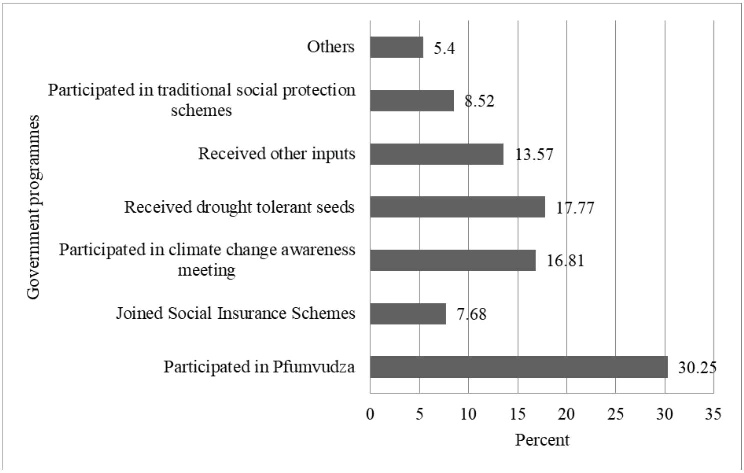

Figure 5.7: Distribution of Smallholder Farmers Participating in Government Programmes

Results presented in Figure 5.7 show that 30.25% of the smallholder farmers participated in the Pfumvudza farming programme, 16.81% participated in climate change awareness meetings, 17.77% used drought-tolerant seeds, and 13.57% received other inputs. Key informants reported that smallholder farmers were assured that Pfumvudza Agriculture promotes food security. Growing drought-tolerant seeds was thought to be an ideal strategy towards dealing with erratic rains for food security. However, there are moments when no rains are received at all, leaving smallholder farmers exposed to food insecurity.

The provision of such inputs saves the farmers from input shortages and also enables them to save money for other basic social services. However, most participants said that Pfumvudza Agriculture is selective and may not achieve the desired results, unless government increases its coverage. They also mentioned that the concept is not new when it came; it was later on given such names as dhiga ufe not dhiga udye, (dig and die and not dig and eat) meaning that it had lost its purpose with people sweating for little or no results. They also lamented prioritisation of the elderly and people with disabilities during the distribution of inputs since it does not have any impact on food security and household social protection. The argument is usually made that provision of inputs creates dependency syndrome.

Seeking Information about Climate Change

Seeking information about climate change is one of the climate change responses that were adopted by the smallholder famers. Smallholder farmers were asked whether or not they ever sought information on climate change adaptation options. The results are presented in Figure 5.8.

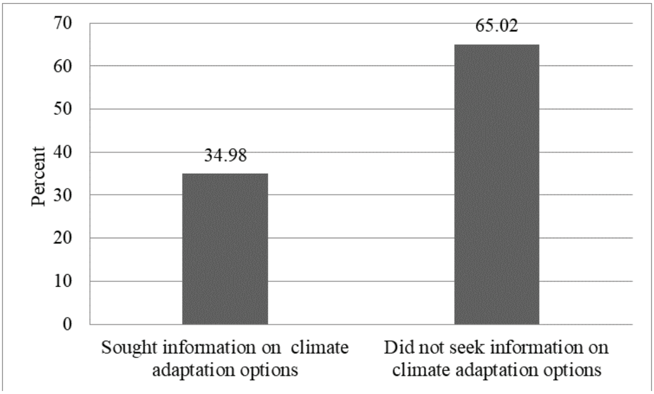

Figure 5.8: Distribution of Farmers Either Seeking or Not Seeking Information on Climate Change Adaptation among Smallholder Farmers

Results presented in Figure 5.8 show that 65.02% of respondents did not seek information on climate change adaptation. It also shows that a total of 34.98 % of the respondents sought information on climate change adaptation.

More knowledge-seeking behaviours on climate change should have ordinarily led to a reduction in the negative effects of climate change. This was, however, clarified by one key informant who noted that the ever-changing climatic conditions have always caught smallholder farmers by surprise, despite their knowledge-seeking behaviours. One of the reasons behind not seeking information as reported in the key informant interviews is ignorance on the impact of climate change on food security. Lack of knowledge on climate change effects on food security has implications on the practising of climate change adaptation strategies among smallholder farmers in Gokwe South. One of the common sources of information referred to by participants was the media through which information on climate change adaptation is shared. This also includes such social media platforms as WhatsApp and Facebook, as well as the internet. Newspapers and radio shows also served as platforms to share climate change knowledge with the local communities.

Strategies to Foster Food Security among Smallholder Farmers

The study findings also reflect on other strategies used to raise household income in order to avert food insecurity. Smallholder farmers were asked about the strategies which they use to secure household food security. Results of their responses are presented in Figure 5.9

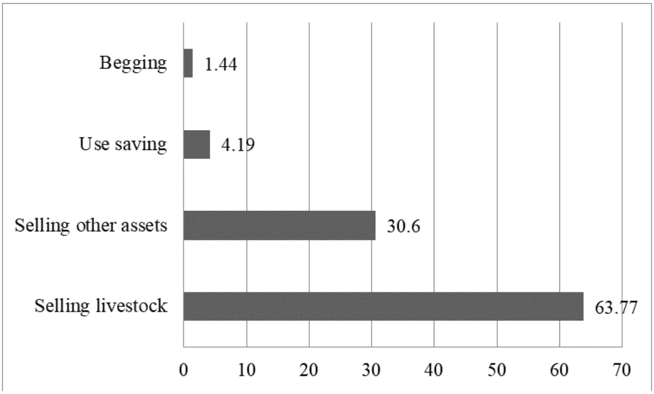

Figure 5.9: Distribution of Farmers Using Other Sources of Income

Results in Figure 5.9 show that 63.77% of the respondents reported that they sold livestock, 30.6% sold other assets, and 1.44% relied on begging to secure food for their households as presented on Figure 5.9. The reasons behind selling livestock relate to non-availability of money to buy food, or desperation in the face of food insecurity at home. All these practices include a form of dissaving which exposes smallholder farmers to insecurity and not having other sources of income when assets get depleted or all livestock sold. Thus, smallholder farmers become poorer due to climate change.

Conclusion

Study findings showed that smallholder farmers are at high risk of food insecurity as their access to stable financial support and adequate rains is compromised. According to the Intergovernmental Panel on Climate Change (Intergovernmental Panel on Climate Change, 2019) report, some of the negative effects of global warming relate to decreased crop quality and food insecurity. It is a fact that livestock and crops are destroyed by droughts which result in poor crop yields and also affect sources of livelihoods. The developments expose many smallholder farmers to food insecurity. Smallholder farmers are finding hope in Pfumvudza Agriculture which was introduced by the Government of Zimbabwe to buttress against food insecurity and poverty among rural communities.

Recommendations

This study was one of the first inquiries into what can be done in order to improve on climate change strategies for food security among smallholder farmers in Zimbabwe. The findings from this study present an opportunity for submission of suggestions to sustain rural livelihoods in a developmental manner. We therefore propose the following:

- The adoption of a multisectoral approach to support smallholders to adapt to climate change.
- Water harvesting through the construction of dams, local boreholes and other water points for the promotion of local livelihoods initiatives.
- Support for smallholder farmers to diversify into other income-generating projects for optimum food security.

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Chapter **06**

Perceived Impacts of Climate Change on Riparian Ecosystem Goods and Services: A Case Study of Rural Communities Living along Mwenezi River, Southeast Zimbabwe

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Introduction

Climate change-induced droughts, increased temperature, rainfall variability, cyclones, floods, heatwaves and disease outbreaks pose a major threat to natural and human ecosystems across the globe (Kupika & Nhamo, 2016). Riparian ecosystems, which comprise the interfaces between terrestrial and aquatic ecosystem (Swanson et al., 1991), have been identified to be particularly susceptible to climate change impacts partly because they are among the world's most transformed and degraded ecosystems (Perry et al., 2012). It has, however, been suggested that riparian ecosystems may be relatively resistant to climate change because they have evolved under conditions of high environmental variability and hydrologic extremes (Catford et al., 2013). They are, according to Capon et al. (2013), hotspots for climate change adaptation since their ecosystem functions and their capacity to adapt, or be adapted to, under changing climatic conditions, will have a significant impact on livelihoods (Thomson et al., 2012).

Riparian ecosystems in semi-arid environments are habitats of critical conservation concern (Maclean et al. (2015) because they provide rural communities with goods and services which support their livelihoods (Kafumbata et al., 2014). They also maintain the integrity of the waterway, reduce pollution, and provide food and habitats to biota (Vyas et al., 2012; Sabo et al., 2005). They are of economic, cultural and ecological importance to the communities (Natta et al., 2002) owing to the fact that they are highly productive ecosystems that are used for both food production and harvesting (Sithole et al., 2012). Any negative change to these goods and services has direct implications on human well-being (Millenium Ecosystem Assessment, 2005). The increasing demand for riparian ecosystem services and the consequent degradation is, however, threatening the ability of the riparian ecosystems to provide these services (Turkelboom et al., 2018). In the absence of adaptation, riparian ecosystems are likely to be highly vulnerable to climate change impacts (Capon et al., 2013).

Four categories of ecosystem services as classified by the Millennium Ecosystem Assessment (Millenium Ecosystem Assessment, 2005) include provisioning, regulating, cultural and supporting services. Communities, including rural households in Zimbabwe, may readily recognise provisioning services, although all the four categories can be impacted by climate change. It is of interest to determine the perceptions of communities on the implications of climate change on social and ecological riparian ecosystem services. Such information is useful in building up initial steps towards developing a dynamic perspective for sustainable ecosystem management of riparian ecosystems under a changing climatic scenario. The information can also be considered in the adaptation planning which should consider all riparian ecosystem functions, goods and services and involve all stakeholders, and not just direct consumers or managers of water (Gleick, 2003).

The risk of losing riparian ecosystem services is worsened by the limited availability of information on the impacts of climate change which can be used to adopt appropriate coping strategies. Such information should be generated because riparian ecosystems are likely to play a critical role in determining the vulnerability of natural and human systems to climate change, and in influencing the capacity of these systems to adapt (Capon et al., 2013). Riparian ecosystems are particularly vulnerable to climate change impacts due to their high levels of exposure and sensitivity to climatic stimuli (Hulme, 2005), and the limitation in terms of their capacity to adapt due to other stressors (Capon et al., 2013). To date, studies on climate change in Chiredzi District have focused on agriculture (Chanza, 2018), and little has been done on riparian ecosystems. The objectives of the study were (i) to determine changes in climatic weather patterns; (ii) to establish local community knowledge of the ecosystems services derived from Mwenezi River and (iii) to determine the perceived impact of climate change on riparian ecosystem services and the adaptation strategies that communities use.

Description of the Study Area and Methodology

The Study Area

The study was conducted in Chiredzi District (18°55'S and 29°49'E), which is located in the south-eastern lowveld of Zimbabwe in Masvingo Province (Figure 6.1). The district is located 365 km south-east of Harare and 215 km east of Beitbridge. The Chiredzi District is in the arid agro-ecological Zone V which is characterised by low rainfall, persistent droughts and low agricultural productivity. It is bordered by Chipinge in the east, Zaka, Bikita, Masvingo and Chivi in the north-west, and Beitbridge and Mwenezi districts in the south-west. Two major rivers, Mwenezi and Runde, flow through the district.

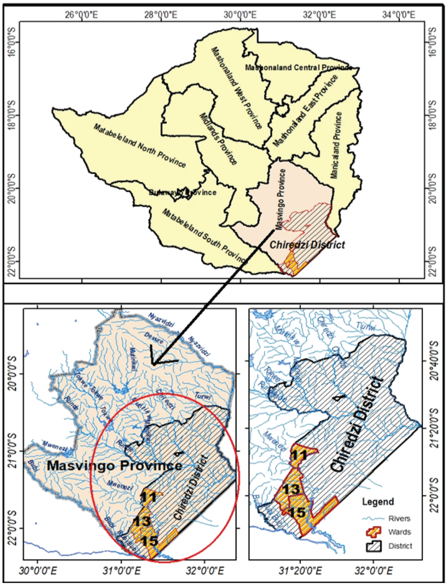

Figure 6.1: Map Showing the Location of the Study Area Research Methods

The study adopted a mixed method approach (Creswell, 2016; Yin, 2015) since the use of either qualitative or quantitative approaches alone is inadequate (Creswell & Clark, 2017). The use of different types of procedures for collecting data and obtaining information from different sources augments the validity and reliability of the data and its interpretation (Saunders et al., 2016). Household questionnaire surveys were used to collect quantitative data, whilst key informant interviews and focus group discussions (FGDs) were used to collect qualitative data.

Study Site Selection and Sampling Methods

Chiredzi District was purposively selected because the area experiences frequent climate change-induced disasters. A relatively high number of the rural population in the area depends on natural resources for its livelihood. Two wards (11 and 15), located one on each side of the river, were purposely selected due to their close proximity to Mwenezi River. A ward is an administrative area which covers an average of 200 ha, consisting of an average of 15 villages of about 40 households each (Jiri et al., 2017), giving an average of about 600 households per ward. Four villages per ward located within a five-km radius of the Mwenezi River were purposively selected for the survey and sampling. Household heads above 30 years of age were interviewed on the assumption that they were knowledgeable about climate change. Key informant interviewees were purposively selected from local experts who had stayed in the area for at least 30 years. The key informants included the headman, village heads and government officials. Focus group discussion participants were selected from those members who exhibited knowledge of climate change.

Data Sources and Collection Methods

Information on temperature and rainfall for the period 1970 to 2019 recorded at Buffalo Range Airport weather station was obtained from the Meteorological Services Department. Qualitative data was obtained using key informant interviews and FGDs. Quantitative data was collected using household questionnaires. The primary data was gathered using ODK. A semi-structured questionnaire was used to collect the data. The household questionnaires included questions on climatic trends, local knowledge on riparian-based goods and services, impacts of climate change on riparian goods and services, and the coping and adaptation strategies. A checklist of questions was used to guide key informant interviews and FGDs. A pilot study to validate and test the reliability of the household survey questionnaire was carried out in Ward 10 by interviewing 25 households. The necessary adjustments were then made. The researchers randomly selected the 159 households for the survey interview.

Table 6.1: Socio-economic and Demographic Profile of Household Respondents in Wards 11 and 15, Chiredzi District

Category	Description	Number of Respondents	Percentage
Administrative unit	Ward 11	87	57.7
	Ward 15	72	45.3
Gender	Male	52	32.7
	Female	107	67.3
Age	19-25	14	8.8
	26-35	41	25.8
	36-45	43	27.0
	46-55	29	18.2
	56-65	32	20.1

Level of Education	No Education	18	11.3
	Literate	5	3.1
	Primary	71	44.7
	Secondary	61	38.4
	Tertiary	3	1.9
	High School	1	6
Marital Status	Married	132	83
	Single	9	6.3
	Divorced	2	1.3
	Widow(er)	15	9.4

Seventeen key informants were interviewed comprising three community liaison officials from Gonarezhou National Park - Chipinda Pools, one Agritex officer and two secondary school teachers, one headman and 10 village heads from the respective wards. The headman and village heads were purposively selected from the participating villages as they are regarded as custodians of traditional laws. A total of two FGDs were conducted in Ward 11 and Ward 15. In Ward 11, the FGD was conducted in Bhatiti Village with 15 participants, whilst in Ward 15 it was conducted in Hlengani Village (Malipati Centre) with 14 participants. Participants for the FDGs were drawn from household heads who had previously participated in the household survey. During FGDs, tools such as resource mapping (concept or system building process of aligning resources in relation to expected outcomes), free listing and ranking were used to gather information from the participants. The FGD moderator ensured that everyone contributed towards the discussions whilst avoiding domination by individuals.

Data Analysis

Descriptive statistics were generated using SPSS Version 21. Demographic data was summarised using descriptive statistics. Key informant interviews and focus group discussions data was transcribed and assigned to pre-determined themes. Temperature and rainfall trends were analysed using the Mann Kendall test, a non-parametric test used to determine the monotonic upwards and downwards trend in time series data (Gocic & Trajkovic, 2013).

Results and Discussions

Temperature and Rainfall Trends in Chiredzi District for the Period 1970 to 2010

The maximum temperature by the Mann Kendall test (tau=0.042, p<0.0001) showed that there was a monotonic trend in temperature (Figure 6.2). The maximum temperature in the area between 1970 and 2010 varied in such a way that it neither decreased nor increased. The minimum temperature (Mann Kendall test, tau=0.069, p<0.0001) also showed a monotonic trend (Figure 6.3). The Sen slope value had a negative effect (-0.032), with a positive intercept value of 80.185, which indicated that there was a significant decreasing trend in minimum temperature. The decrease in minimum temperature is causing cold spells in Chiredzi District. Minimum temperatures in the area exhibited a downward trend, while the maximum temperature is relatively stable.Although the maximum temperature did not exhibit an increasing trend, key informants indicated that temperatures have changed in the district. Extreme heatwaves are now being experienced especially between August and December. The extreme heatwaves experienced in November 2019 resulted in the death of chickens. Communities reported heatwaves due to excessive increase in temperature. Most African regions are warming at a fast rate (Cook & Vizy, 2015; Engelbrecht et al., 2015), resulting in high temperatures and high evapotranspiration (Swelam et al., 2010), which in turn results in water stress. This affects primary productivity and food production, which are supporting and provisioning ecosystem services, respectively (van der Geest et al., 2019). Droughts are also prevalent, resulting in a high mortality rate of livestock.

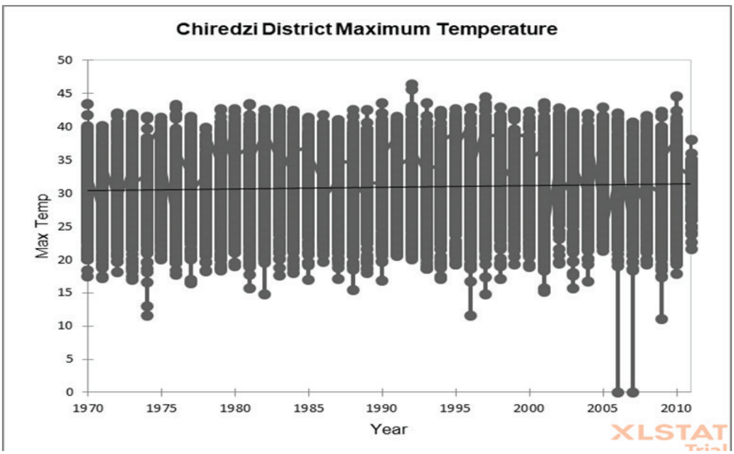

Figure 6.2: Temporal Variation in Annual Maximum Temperature for Chiredzi District (1970-2010)

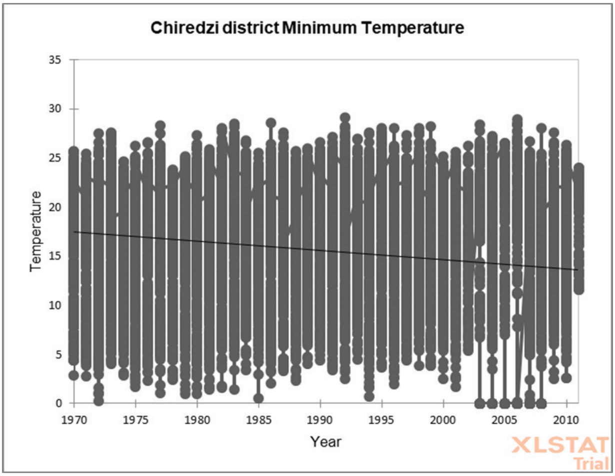

Figure 6.3: Temporal Variation in Annual Minimum Temperature for Chiredzi District (19702010)

Temporal variation in rainfall is shown in Figure 5.4. The Mann Kendall test (tau= -0.122, p>0.26) showed a significant gradual decline in annual rainfall from 1970 to 2010. Key informants indicated that changes in rainfall patterns are being experienced in the area mainly from October to late January.

Erratic rainfall patterns being experienced in the study area can be attributed to climate change as suggested by Dumenu and Obeng (2016), and this is causing variability in surface water (Taylor et al., 2013) as shown by changes in the flow pattern of Mwenezi River. Rainfall variability and late and short rainfall seasons observed by communities in Chiredzi threatens the livelihoods of the rural communities, and also poses risks to rain-fed farming in this semi-dry agro-ecological zone (Chikozho, 2010). Increased intensity and length of droughts in Africa is now a common phenomenon (Panel, 2012). Rainfall is becoming less dependable due to its decline of 10% and 20% (Turco et al., 2015).

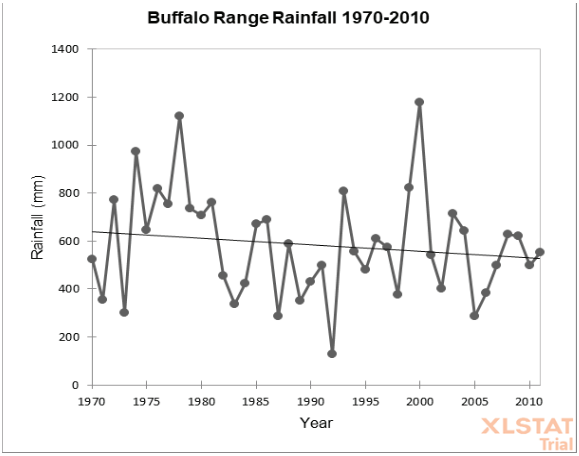

Figure 6.4: Temporal Variation in Rainfall in Chiredzi District (1990-2010)

Respondents from the household survey, 66.1% (N = 159), indicated that climatic conditions have been changing in the area.

One of the participants during a focus group discussion had this to say:

In 1990 it was extremely hot and we received low rainfall, in 1992 we experienced a severe drought, while in1994 the harvest was better, and in the year 2000 heavy downpours resulted in destructive floods, but we harvested a good yield. In 2005, it was extremely hot, and the 2019/2020 season had severe drought leading to high livestock mortality.

It was highlighted during the focus group discussions that cyclones are now a common phenomenon in the area. Participants indicated that they started observing them in the year 2000, and again in 2007, then 2017, and the recent 2019 Cyclone Idai, though the impact was not severe. Dry spells were first experienced in 1972, then recurred in 1997, and the frequency increased as from 2013. Rainfall seasons are becoming shorter, unpredictable and erratic. Rainfall onset has shifted significantly. Rains used to start in September in the 1970s, which used to be called Bumharutsva. In the 1980s, the first rains were received in October, and in November in the 1990s. However, as from 2000, the onset of rain has been in January, but in 2019 it was in February. The shift in the onset of rains has affected the flow of the Mwenezi River. The river now floods between October and January, and is dry from August to December. Focus group discussions indicated that the Mwenezi River flow is normally very high between November and March, low from April to July, and very low between August and October.

Perceived Impact of Climate Change on Provisioning Ecosystem Services

Table 6.2: Percentage of Household Awareness of Ecosystem Services and % Reporting Changes in Ecosystem Services along the Mwenezi River Due to Climate Change over 10 Years

Ecosystem Goods and Services	% of Respondents Using Different Ecosystem Services	% of Respondent Reporting		
		Low	Medium	High
Provisioning				
Fruits	20.8	15.7	22	62.3
Fish	47.2	17.6	15	67.3
Wood	22	20.8	22.6	56.6
Clean Water	54.1	19.5	27.7	54.7
Cultural				
Inspiration	47.8	27	22.6	50.3

The respondents from the household questionnaire survey recognised ecosystems services (Table 6.2) obtained from the ecosystem along the Mwenezi River which include water, fish, wood, fruits and medicinal plants (Table 6.2). The most common ecosystem goods and services are clean water, fish, fibre, wood, fruit and medicinal plants which are being used by 54.41%, 47.2%, 45.3%, 22%, 20.8% and 16.4% of the households, respectively.

Water

Participants in focus group discussions said that people in Chiredzi District residing in wards 11 and 15 depend on the Mwenezi River for clean water which is filtered by riparian vegetation like sedges. The community uses the water mainly harvested from the river for household use (watering gardens and drinking), and to water livestock and wildlife. According to the FGD participants, between December and April when the river flow is high, people fetch water directly from the river for household use, whilst between May and November, local communities adapt by digging temporal wells along the riverbed. Results in Table 2 show that 54.7% of the responded reported that they have experienced a reduction in clean water over the last 10 years. The communities said that the prolonged dry spells, reduced rainfall and excessive temperatures lead to a decrease in the quantity and quality of clean surface water. According to the community members that attended FDG meetings, water quality has also deteriorated due to low discharge during the longed dry spells. The wells are exposed to pollution due to competition for use with livestock and wildlife. The researchers observed that during the dry period, plant productivity along the river, which contributes to the natural purification of the water, deteriorates due to changes in land use and overgrazing. During the dry seasons and drought periods, livestock utilises the riverbed for forage, and this has affected the growth of reeds and sedges which play a pivotal role in the water purification process. Polluted water exposes communities to gross health issues. One of the informants mentioned that sometime in 2017, people in Ward 11 suffered from the outbreak of diarrhoea due to consumption of contaminated water.

Fish

Communities depend on fish for nutrition. Common species harvested in the Mwenezi River include Oreochromis niloticus, O. macrochir, O. mossambicus, Tilapia rendalli, Labeo altivelis, Clarias gariepinus and Hydrocynus vitattus. Results in Table 6.2 show that 67.3% of the respondents reported a decline in fish production over the last 10 years. One of the fishers interviewed said that fish quantity and size has decreased. Tigerfish and Banded jewel cichlid have since vanished as these species are very sensitive to water quality. Some other species have decreased in size, with the exception of Clarias gariepinus, due to its adaptation strategy. This observation is supported by Yousefi et al. (2020) and Lam (2020), who observed that climate change alters the phenology and distribution of freshwater species due to changes in suitable habitats. This is tandem with the community observation on the impacts of climate on the availability of fish. Five pools (Malipati, Malisheshe, Fweva, Ngwenyama and Nwashali) in the Mwenezi River retain water after the river stops flowing, and these provide habitat for fish and other aquatic species.

The researchers observed that the decrease in stream flow, coupled with high water temperature and high nutrient loading, promotes alga blooming which in turn has contributed to the decline of fish species due to the competition of dissolved oxygen. According to some key informants, the decline in the Mwenezi River flow is severe and has caused the drying up of some seasonal pools. This has caused a reduction in groundwater availability. The decrease in the fish population has implications on the human community well-being.

Wood

Riparian-based communities rely on wood fuel for energy and construction of shelter. The riparian is also endowed with Terminalia sericea which provides several services, for example, fencing poles. This is because the wood is termite-resistant, the leaves provide a blue dye, while the leaf hairs are used for glazing pottery. One key informant mentioned that a walking stick (tsvimbo) from Terminalia sericea is often stuck on the floor of a shrine to facilitate communication with the ancestral spirits. Mopani (Colophospermum mopani) trees provide strong poles. These provide habitat for mopane worms which are harvested for their socio-economic value. The wooded forests act as windbreaks in Chiredzi. FGD participants agreed that the between August and October, the area experiences strong winds, but their impact is reduced by the forest wood. Woodlands also act as environmental stabilisers since they reduce erosion in times of heavy rainfall downpours.

Results in Table 6.2 show that 56.6% of the respondent reported a decline in the availability of wood over the last 10 years. The FGD participants reported that people who practise riverbed cultivation use wood for fencing their gardens and fields to reduce crop raids. Communities living along the riparian zone harvest timber for building and for roofing material for houses, hence its demand has been increasing with the increase in population growth in the area. According to one key informant, the lack of alternative income generating projects has forced young people to engage in craftwork which uses wood material harvested from the riparian zone. It was reported that the quality of the wood has been deteriorating due to over-harvesting and decreased plant growth.

Fruits

Focus group participants reported that the riparian zone provides fruits for human consumption and as supplementary feed to their livestock. The harvested fruits include governor's plum (Flacourtia indica), marula (Sclerocarya birrea), snot apple (Azanza garckeana), monkey bread (Piliostigma thonningii), sour plum (Ximenia caffra), wild custard apple (Annoni senegalensis), smelly berry finger leaf fruit (Vitez mombassae), wild grape (Lannea edulis), monkey orange (Strychnos sp.) and masawu (Ziziphus abyssinica). The riparian zone also provides forage for livestock. According to Egoh (2002) and Shackleton et al., (2007), wild fruit and food collection from the riparian ecosystem are important for communities since they contribute approximately 28% of the gross income of rural livelihoods (Shackleton et al., 2007). Results in Table 6.2 show that 62.3% of the respondents indicated that the fruits trees are now being threatened by climatic extremes. This disrupts food availability and has nutritional implications. Loss of this service deprives the rural communities of Chiredzi of the maximum benefit from this provisioning service.

Cultural Inspiration

The riparian zone provides cultural services to communities for spiritual enrichment, mental development and leisure. The Mwenezi River supports five pools, namely, Malipati, Malisheshe, Fweva, Ngwenyama and Nwashali, which form after the river stops flowing. Besides the provision of water for livestock, the pools also provide recreational fishing. The pools and the riparian zone provide habitats for various fish species, and birds and animals like hippos (Hippopotamus amphibious), bushbuck (Tragelaphus scriptus), crocodiles (Crocodylus acutus), elephants (Loxodonta africana) and other wild animals, thus fulfilling the value of recreation and aesthetic. Nwashali and Chikalapuwa pools are used for traditional ceremonies, a very critical component of the African tradition. Results in Table 6.2 show that 50.3% of the respondents reported a decrease in the cultural value attached to the pools. They attributed the decline to an increase in Christianity and the seasonal drying up of the pool following severe droughts.

Conclusion

In conclusion, the study showed that communities living along the Mwenezi River readily recognised ecosystems goods and services. They have obserseveral changes in the climate, including the delayed onset of the rain season, increasing drought incidences, erratic rainfall, increased temperatures, cold spells and heatwaves. Chiredzi District rural communities have perceived some changes related to climate change within the riparian zone, and these changes have affected their livelihoods in terms of the availability of natural capital. The occurrence of dry spells has a significant impact on household food security (Nyikahadzoi et al., 2017; Moyo, 2020). Intermittent rainfall affects agriculture productivity, the main livelihood source. Of note is the fact that the heatwaves and cold spells being experienced in the area are now common in other parts of Zimbabwe (Kupika et al., 2019; Lunduka et al., 2019; Mustafa et al., 2019). As a result, Chiredzi rural communities have adopted coping strategies in response to the changes in climate.

Recommendations

This study shows that the riparian zone is an important safety net under a changing climate, which should be sustainably managed to promote community and ecosystem resilience. Sustainable adaptation strategies should be promoted to avoid the disruption of fundamental riparian ecological functions and the consequent disruption of local livelihoods (Butler et al., 2012). Consideration should be made towards the development of riparian ecosystem services management strategy nationally.

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Chapter 07

Rural Communities Understanding of Flood Disaster Risk: A Case Study of Tsholotsho District, Zimbabwe

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Introduction

Natural disasters are a growing threat to human livelihoods, especially with the unfolding climate change whose effects have indirectly resulted in the loss of human life, injuries and destruction to property and infrastructure (UNISDR, Global Assessment Report on Disaster Risk Reduction, 2009; WCDRR, 2015; Berg & De Majo 2017; UNOCHA, 2019). The world has recorded a marked increase in the occurrence of natural disasters and, of these, flooding is the most prevalent (UN/CRED, 2015; World Economic Forum, 2016).

In response to the above natural disaster-related challenges, the UNISDR coordinated the global agreement known as the Sendai Framework for Disaster Risk Reduction: 2015-2030. The global agreement is a 15-year, voluntary, non-binding agreement which recognises that the state has the primary role in reducing disaster risk. It was endorsed by the United Nations General Assembly and was ratified by 137 states, including Zimbabwe. The framework is underlined by the understanding that effective disaster risk management begins with understanding the risk itself, and in Tsholotsho District it is flood disaster risk, through joint assessment involving experts and at-risk communities (CADRI, 2017). The framework aims to achieve a substantial reduction of risk and losses in lives, livelihoods and health, as well as in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries. It has four priorities for action, namely, (i) understanding disaster risk (ii) strengthening disaster risk governance (iii) investing in disaster risk reduction for resilience (iv) enhancing disaster preparedness for effective response and building back better (UNISDR, Sendai Framework for Disaster Risk Reduction, 2015).

The purpose of the study was to analyse rural communities' understanding of flood disasters in line with the Sendai Framework for Disaster Risk Reduction: 2015-2030. The study employed a descriptive case study research design. Data was collected using a survey questionnaire, and key informant interviews were used to solicit information from the affected communities, as well as the District Civil Protection Unit. A disaster risk understanding model was developed, which shows the three main factors that influence understanding of disaster risk. Opportunities for disaster risk reduction in Tsholotsho District lie in the villages' organisational structure, the presence of non-governmental organisations as well as departments like the President's Office, the Environmental Management Agency, Agritex, and the Forestry Commission. All these are channels that can be used for communication and dissemination of disaster information, thereby enhancing the locals' understanding of disaster risk. The chapter seeks to assess the extent to which the Sendai Framework's first priority area is being implemented in the context of Zimbabwe in general and Tsholotsho District in particular.

Background to the Study

There has been a marked increase in the occurrence of natural disasters worldwide, and of these, flooding is the most prevalent. From 1995 to 2005, flooding has been the most common natural disaster, accounting for 43% of all recorded natural disasters (World Economic Forum, 2016). In a joint report with the UN Office for Disaster Risk Reduction, the Centre for Research on the Epidemiology of Disasters recorded 3 062 natural flood disasters between 1995 and 2015 (UN/CRED, 2015). A number of definitions of what a flood is have been put forward by various authors with marked differences in the source of water, the economic loss and the statistical occurrence. The researchers deduced that most authors give definitions of floods relevant to their country or area of study. Floods strike in Asia and Africa more than other continents and countries. In Asia, floods are mostly caused by tidal waters and riverine floods. With this in mind, Chen (2007) defines a flood as the submergence by water of a usually dry land area from an overflow of tidal or inland waters from the usual and rapid accumulation of runoff of surface waters from any source. Zimbabwe's State of Environment Report (SOER) defines a flood as an overflowing or influx of water beyond its normal confines (Chenje et al., 1998). Recently, unprecedented incidents of flooding have resulted in massive disruption of human societies. Globally, between 1970 and 2009, singular tropical cyclones have amassed the highest death toll (Bhola in Bangladesh, 1970 killed 300 000) and greatest damages (Katrina in USA, 2005, US$125 billion worth in losses) on record (EM-DAT: The OFDA/CRED International Disaster Database, 2011). Altogether, these tropical cyclones claimed a cumulated reported toll of 789 000 lives during this period in the year 2010 alone.

In Africa, in 2010 alone floods contributed 82.6% of all disasters that occurred on the continent, a rise from 66.5% in 2009 (Balgah et al., 2015). Zimbabwe has been affected by floods over decades, and the most common types of floods in Zimbabwe are riverine, rain-induced and cyclone-induced floods and the floods that occur as a result of dam failure. Cyclone-induced floods are those that occur as a result of tropical cyclones such as Cyclone Eline in 2000, Cyclone Dineo in 2017, and Cyclone Idai 2019 in Zimbabwe. Floods tend to occur in the southern and northern low lying areas of Zimbabwe, in the paths of cyclones, in between river confluences and downstream of major dams. Tsholotsho District, the study area, has experienced floods from as early as 1978. In 2000, Cyclone Eline led to devastating floods which affected most districts in the Zambezi Basin, including Tsholotsho (Government of Zimbabwe, 2005). Incessant rainfall in the 2013/2014 rainfall season led to flooding in Tsholotsho District (ZHRC, 2015) and, recently, Cyclone Dineo in 2017 saw the greater parts of wards 5 and 6 flooded in the district.

When looking at flood disasters, a number of factors influence vulnerability, and chief among them is climate change (Inter-governmental Panel on Climate Change, 2014; Below et al., 2012; Simon & Leck, 2010). Climate change has affected and influenced the frequency of shocks (flood disasters) and stressors (seasonality, trends over time). Climate change is likely to exacerbate this trend in the near future (Adikrai et al., 2010; Intergovernmental Panel on Climate Change, 2007), and simulations using high‐resolution models have indicated that the intensity and frequency of tropical cyclones and heavy precipitation events will increase with time as a result of global warming (Zhao & Held, 2012; Murakami et al., 2012; Knutson et al., 2010).

Historically, floods were perceived to be 'the acts of God', as disruptions to normality (Mauch, 2009). Responses were premised on the assumption that floods were external events that affected an unknowing and unprepared society, but this has changed with the realisation that some factors and humans themselves play a role in exacerbating the incidences and impacts of flood disasters (Zevenbergen et al., 2013). Matunhu (2012) discusses how increased levels of poverty in Africa have forced people to live under vulnerable conditions. The United Nations Development Programme (1992) stresses that poverty has forced people in some communities to live in temporary, unsafe shelters in crowded places, thereby exposing them to flood risk.

The vulnerability context of Tsholotsho District cannot be described in terms of climate change only, but poverty and proximity to the Gwayi River make the communities more vulnerable to flood disasters. In 2017. The continual build-up of runoff on the surface of the ground as a result of incessant rainfall and the subsequent bursting of the Gwayi River resulted in the destruction of communities settled along the river (CADRI, 2017). In Tsholotsho, communities settled along the Gwayi River in order to increase agricultural productivity. Only 2.7% of the population is urbanised, and the rest (97.3%) lives in rural areas. Resultantly, the main economic activity in Tsholotsho is farming. The soils are bad for cultivation except for the black clay soils along the Gwayi River. Following the destruction of homesteads during Cyclone Dineo, 859 people were relocated to Tshino and Sawudweni, 143 and 176 families, respectively, and new houses were built for them by the government (Inter-Agency Flooding Rapid Assessment Report Tsholotsho District, 2017).

The 2017 flood disaster is also responsible for internal displacement in the district. Assessment of the displacement period and the push factors indicate that most of the displacement in the affected areas in Tsholotsho were due to floods caused by Cyclone Dineo during the 2016/2017 rainy season. The Zimbabwe Displacement Report Tsholotsho District (2018) alludes to the fact that the displaced population is estimated at 476 internally displaced (IDP) households or 2 343 IDP individuals. One hundred percent of displaced households live within the host community, and Ward 6 was the most affected by floods with a total of 374 displaced households or 1 870 IDPs, which represents 75% of the IDP caseload identified throughout the assessed wards.

This chapter focuses on the communities of wards 5 and 6, which have been repeatedly affected by floods since 1978, and analyses their understanding of flood disaster risk. This is based on the recent global framework, the Sendai Framework for Disaster Risk Reduction, to which Zimbabwe is a signatory. The framework has four priorities for action as well as seven global targets, and the expected outcome and goal is "the substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries" (UNISDR, Sendai Framework for Disaster Risk Reduction, 2015). The Sendai Framework's priority is 'understanding disaster risk'. It stipulates that policies and practices for disaster risk management should be based on an understanding of disaster risk in all its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment (UNISDR, 2015). The purpose of this chapter is therefore to zero in on affected communities who are important stakeholders in disaster risk reduction, and assess their knowledge and understanding of flood disaster risk

Description of the study area and methodology

Study Area

The study was carried out in Tsholotsho District, Matabeleland North Province. The district has been affected by floods from as early as 1978 as a result of incessant rainfall and tropical cyclones (Meteorological, 2008; ZINWA, 2008), Cyclone Eline in 2000 (Government of Zimbabwe, 2005) and Cyclone Dineo in 2017. Figure 7.1 shows the location of Tsholotsho District on the map of Zimbabwe and the two wards in which the study was undertaken. The district has two principal rivers, Manzamnyama and Gwayi. Gwayi River is part of the Zambezi Basin, which is an international river basin. The Zambezi Basin forms one of the seven catchments in Zimbabwe (Pawaringira, 2008).

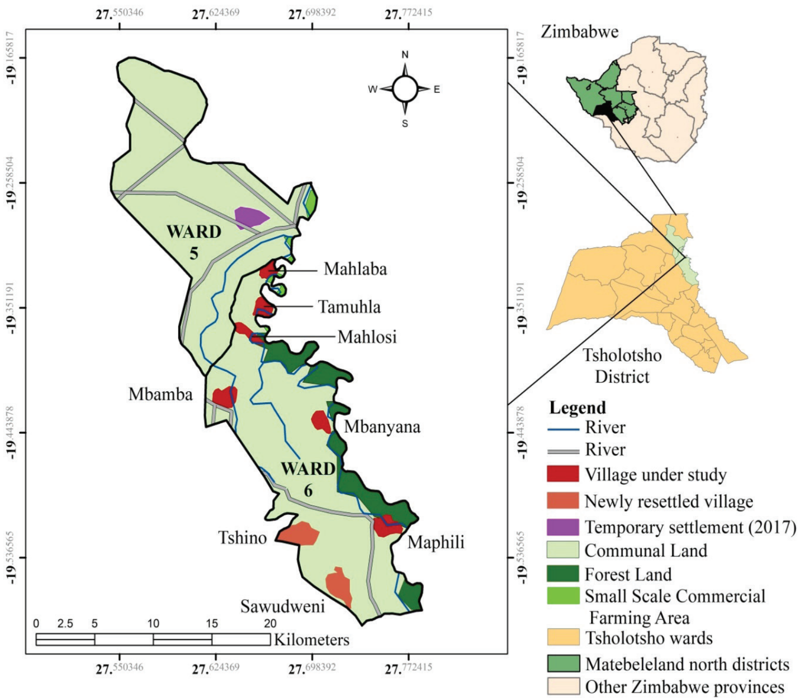

Figure 7.1: Study Area Map of Tsholotsho District

Gwayi River runs through wards 5 and 6 (Sheleni), and it is these villages which are most vulnerable to floods. Tsholotsho District experiences a warm semi-arid climate (BSh- Mid-Latitude Steppe and Desert Climate). According to Koppen's (2016) climate classification, this is the climate of regions that receive precipitation below potential evapotranspiration, but not as low as a desert climate (Zifan, 2016; Chen, 2013). Tsholotsho falls under agro-ecological region IV, receiving an average of about 650 mm per annum (Meteorological, 2008; Heinrich et al., 2004). The district receives little rainfall throughout the year, and most precipitation is received between December and March, with monthly averages of 136 mm. The district has an average annual temperature of 27.8 0C, and its maximum monthly temperatures are experienced from October to February (Meteorological, 2008). The Gwayi River areas in wards 6 and 5 are characterised by rich black soils which fall within a 2 km wide belt of the Gwayi River (Pawaringira, 2008). Soils in the rest of the district are mainly derived from felsic (gneissic) rocks, giving rise to the deep Kalahari sands. Kalahari sands are bad for cultivation except for the black clay soils along Gwayi River. The Kalahari sands are good for cattle rearing, though they need massive investment in terms of reliable water provision and disease prevention. Loss of lives, livelihoods and assets as a result of flooding in Tsholotsho has in turn been a result of settlements along the Gwayi River and inaccurate weather forecasts.

Research Methods

The research used questionnaires, interviews, focus group discussions and observation. Simple random and purposive sampling methods were used to select participants from the affected people.

Study Site Selection and Sampling Methods

The basic unit of analysis was the communities in wards 5 and 6 that have repeatedly been affected by floods since 1978. Within the two wards, two villages, Tshino and Sawudweni were selected for this study. These were selected because of the rich knowledge that they possess as the most recent flood disaster victims in Tsholotsho, given that they experienced some of the worst effects of flood disasters. From a list of affected household, simple random sampling was then used to select a 20% sample size from the affected people. A total of 172 households that were affected by the most recent floods were selected, 77 from Tshino and 95 from Sawudweni. Purposive sampling was used to select the NGOs and members of the District CPU for indepth interviews. The District Civil Protection Unit officials are responsible for the overall coordination of all stakeholders involved in disaster risk management. The District Administrator, EMA District Environmental Officer, Rural District Council Chief Executive Officer and Agritex Field extension agent were selected for indepth interviews.

Data Sources and Collection Methods

Qualitative data was collected using semi-structured interviews with representatives of the NGOs and members of the Civil Protection Unit, particularly on their role in educating communities about flooding. The researchers used two interview guides, one for the community members and the other for district civil protection members and the NGOs which operate in the two wards. The interviews guides were used to give room for follow-ups to be asked, whilst also allowing the researcher the flexibility to pursue an idea in some responses in more detail. The researchers conducted interviews with representatives of each stakeholder of Tsholotsho District CPU, and these are namely, the District Administrator, Forestry Commission, Veterinary Services, Agritex, Environmental Management Agency, Tsholotsho Rural District Council and Social Services Department.

Quantitative data was collected using a household survey questionnaires. The questionnaires were administered by the researchers to ensure a high response rate and to clarify some issues to the respondents in the local language (Ndebele) where necessary. The questionnaires were used to collect the demographic data of the respondents and household knowledge of the risk of flooding.

Data analysis Procedures

Thematic coding was used to analyse the qualitative data from the key informant interviews and focus group discussions. The researchers coded the data, according to themes. Quantitative data was analysed using SPSS (20).

Results

Demographic Characteristics of the Respondents

The study sample comprised an equal number of both men and women (n=172). The ages of the respondents ranged between 15 years and 84 years. Fifty-two percent of the respondents attained primary level education, followed by 20% for ordinary level. Seventeen percent attained the Zimbabwe Junior Certificate of Education, 9% attained advanced level education, and 2% of the respondents had never been to school. All the households had at least two members of the family currently in school, and only 27.5% had family members in primary school, while the rest (62.5%) had at least one family member at secondary level.

Communities' Awareness on Vulnerability to Floods

How the 2017 Flood Victims Knew They Were at Risk of Flooding

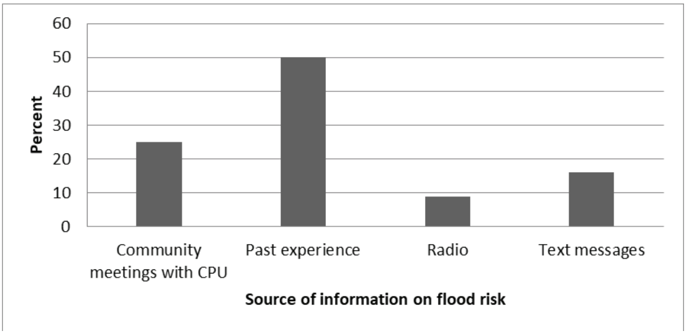

Figure 7.2: Communities Source of Information on Flood Risk

Results in Figure 7.2 show that 50% of the respondents perceive hazard risks based on past experience. Given the emergence of experience as an important source of information used to detect pending flood risk, the researchers sought to establish the available information that the community is relying on.

Indigenous Knowledge and Understanding of Flood Disaster Risk

Study findings from both the questionnaires and FGDs show the significant role played by IKS in disaster preparedness and prediction. For example, respondents highlighted that with each rainfall season that comes, they study the sun and the moon. If there is a circle around the sun or the moon at the beginning of the rainy season, they believe that they will have heavy rains that year, hence the high likelihood of flooding in that year.

Results from the survey show that 89% of the respondents were familiar with dark clouds which hang very low as a sign of impending heavy rains. During key informant interviews, words like 'pregnant cloud' and 'full clouds' were used to describe these clouds which, according to the respondents, often look like they are going to burst with showers and thunderstorms of precipitation. From their description, the villagers were referring to cumulonimbus clouds which, according to the United Kingdom Meteorological Office (2018), are heavy and dense low-level clouds, extending high into the sky in towers. The base, which is often flat and very dark, and maybe a few hundred feet above the earth's surface, is associated with extreme weather such as heavy torrential downpours

Water Level in Rivers

Several elderly respondents referred to the foaming and frothing of the Gwayi River as a sign of imminent flooding. When the elderly see these signs, they encourage villagers to cross the Gwayi River on amazibuko (temporary footbridges) even if the river is not yet flooded. The foaming and frothing are early signs of imminent flooding.

Vegetation Signs

Eighty-one per cent of the respondents mentioned ukuhluma kwezihlahla (the growth of new tree leaves and flowers) as a sign of imminent heavy rains. An elderly woman, aged 84 years, went into detail about the types of trees she particularly takes note of — if the velvet wild medlar (Vangueria infausta) or the snowberry tree (Symphoricarpos albus) produces a lot of fruits or the umbrella thorn has a lot of flowers, it is a sign that heavy rains are imminent. In science not much has been documented on how the flowering of trees can be a sign for imminent rains or that of plenteous fruits being harvested, except a few research on the mock orange tree and the Brugmansia whose flowering is believed to be a sure sign of heavy rains (Daily Mercury, 2016).

Animal Behaviour

According to some key informants, animal behaviour can predict the incoming of floods or natural disaster. For example, when dogs are uneasy, evidently afraid, following their owners everywhere and abandoning their usual sleeping place and opting for higher or more elevated places, it is a sign that a heavy downpour is coming. A group of elderly people that were interviewed said that when birds build their nests in higher branches, it means that flooding is imminent. The elders also pointed out that the jackobin cuckoo (Clamator jacobinus) usually becomes unsettled, making a continued sound — bird cry, before a heavy downpour that can result in flooding. They also pointed out that the unusual moving around of many ants as if they are in a hurry signifies that heavy rains are coming.

Study findings also show that 25% of the respondents knew they were at risk of flooding as a result of community meetings with the CPU. The results reflect on the less influential role of radio (9%) and text messages (16%) during the pre-disaster and post-recovery stages. Most of the respondents alluded to the fact that although they were aware of all the warning signs from the council meetings and the phone text messages, they did not believe it would be so. Thus, they did not make any effort to move. Relative to the IKS, the institutional role of CPU (25%) has had limitations in capacity building and dissemination of information on risks and uncertainties associated with rapid onset disasters like Cyclone Idai.

Communities' Response to Flood Disaster Risks

In response to impending floods, 50% of respondents indicated that during the last disaster phase, they attended community meetings on disaster preparedness, of all the options provided during the preparedness meetings. Only 25% of the respondents living in low lying areas moved to higher ground to minimise susceptibility to flooding. The reluctance to relocate shows that most residents are unwilling to leave their homesteads owing to their attachment to them despite imminent pending risks of floods.

Twenty-five percent of the respondents stocked up essentials such as food and medication. The rest of the households were food insecure and lacked basic medication to cope with disaster-related ailments, mainly because they did not have the resources or did not see the need to do so. Thirty percent of the respondents indicated that they elevated their structures, such as the fowl-runs and the granaries to make sure they were not swept away by the floods. The respondents listed that they always stay put and hope to survive the floods, climb on top of huts and trees and construct temporary structures a few metres from the destroyed shelters in order to watch their property and livestock. Most of the males, particularly those aged 15-25 years, said they climbed on top of the huts during flooding, completely ignoring the fact that the structures are not very strong and are highly liable to collapse, besides being exposed to another possible hazard of being struck by lightning. Sixty-two percent of the respondents temporarily moved to a nearby relative or friend's place, but this was mostly women and children, while the men stayed behind. Most residents said because of fear of having their livestock stolen, particularly chickens and goats, they would rather endure the increasing level of water until "it got unbearable", then they would consider moving to higher ground. To most residents, despite pleas from the District Environmental Health Office, moving to higher ground is only a temporary solution to floods, a response mechanism they adopt when the worse comes to worst. It is not seen as a permanent solution, that is why even though residents were given new houses in Sawudweni and Tshino, they still continue to live at their old homesteads where farming activities still continue. After the floods had receded, 33% of the households that relocated did not stay permanently at their new home. They kept the old home because that is considered to be their culturally home, where dead relatives were buried. Moreover, the old homestead maintained its economic value because that is where household fields are located. Despite the number of awareness campaigns and encouragements for households to relocate to higher ground, very few households did so. With regard to Cyclone Dineo flood disaster statistics, the results show that 90% of the respondents did not have any of the flood disaster information communicated to them, though a number of government reports were compiled about the disaster.

Discussion

While the global community is governed by policies and frameworks like the Sendai Framework, which advocate for institutional capacity building and joint assessment, the realities on the ground paint a different picture. Results from this study show that the majority of respondents perceive hazard risk based on their experiences with flood disasters. Such a phenomenon validates the supremacy of indigenous knowledge systems in understanding and characterising the vulnerability context dominated by floods as shocks. In fact, the Sendai Framework recognises the role of indigenous knowledge systems in risk identification and characterisation, as well as its potential to augment scientific knowledge in disaster risk assessment. Some of the indigenous knowledge has scientific backing. In science, there is an old weather saying which says, 'A ring around the moon means rain soon' (EarthSky in Space, 2015) and, according to Kershner (2018), the halo around the moon is a refraction of the light of the moon through ice crystals. These ice crystals make up cirrus clouds, and though they do not necessarily bring storms, they do precede some low-pressure systems by a day or two, and low-pressure systems do bring precipitation storms. According to EarthSky (2015), a solar halo as well means the same thing.

Overally, indigenous knowledge, though vital in flood disaster risk reduction, particularly where prediction is concerned, has its own limitations. Indigenous knowledge is not found in all generational classes and also lacks documentation. Also affecting reliability and sustainability is the fact that oral tradition has become distorted, and there are increasingly few older adults who know the raw and undiluted version of indigenous knowledge in flood disaster management.

Communities at risk of flooding and the affected ones should have post-disaster statistics communicated to them, either in village meetings, schools or using print media as appropriate in order to foster an understanding of disaster risk. This will, in turn, encourage change and ultimately reduce disaster risk in Tsholotsho District. This is in line with priority one of the Sendai Framework which also alludes to the pertinence of the systematic evaluation, recording, sharing and public accounting for disaster losses. The same framework also alludes to an understanding of the economic, social, health, education, environmental and cultural heritage impacts as appropriate, in the context of event-specific hazard-exposure and vulnerability information in order to fully attain improved levels of understanding disaster risk (UNISDR, Sendai Frameowrk for Disaster Risk Reduction, 2015). Currently, the communities' awareness on flood hazard characteristics echoes the findings of Knocke and Kolivras (2007) who submit that there is currently a knowledge gap between flood experts and the general public about the level of perceived risk to floods. This seems to be the case in Tsholotsho District. Of importance are the possible health disasters like cholera and malaria that could emanate from flood disasters. These are equally life-threatening, and though health workers and a number of NGOs educated the people on this at a resettlement camp in Sipepa before the houses were built for them, it is imperative that this information be shared before disaster strikes.

Towards a DRUM Management Framework

In terms of understanding risk information, this research unearthed a number of important factors that influence disaster risk understanding. These factors are grouped into three main categories: socio-economic, political and environmental (Figure 7.3).

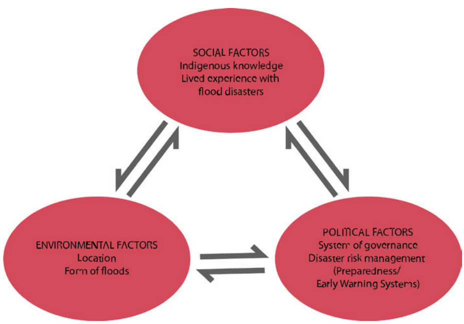

Figure 7.3: Disaster Risk Understanding Model (DRUM)

Social factors such as indigenous knowledge greatly influence the level of understanding disaster risk, especially in a rural community like Tsholotsho District. This is the knowledge the community believes to be true and effective because it has been tried and tested and found to work over generations. Given the positives and negatives of indigenous knowledge, it still influences an individual's capacity to recognise and understand risk. Political factors such as the prevailing system of governance influence communities' understanding of disaster risk. The system of governance (top down approach) and the district's disaster management determine what kind of workshops and awareness campaigns are held, where and how frequently. The dispersion of information is mainly by word of mouth through traditional leaders. This has a bearing on communities' understanding of flood risk because information can be distorted from one person to the next. Looking at environmental factors, the location or environment in which one grows up influences their perception of risk. Witnessing the form of floods themselves fosters an understanding of disaster risk, especially for communities along the Gwayi River (Sheleni line) who saw the river spilling and failing to follow streams. Lived experiences of flood disasters also influence understanding disaster risk in both the positive and negative in that it can improve communities' ability to recognise risk, but can also make them complacent to warnings because they have come out unscathed in the past.

Conclusion

From the research, contrary to popular belief that communities living in disaster-prone areas are very knowledgeable when it comes to the natural disasters affecting their particular communities, results from this study show that this is not always the case. Communities in the district are very much aware of the fact that they are vulnerable to floods. However, their knowledge seldom culminates in appropriate action like permanently moving to higher ground before a disaster. Results show that communities have an attachment to their habitual homesteads (though flood-prone areas), which have graves of the late family members, as well as fertile soils. This has resulted in the loss of livestock and property, which otherwise could have been avoided. The essence of awareness of vulnerability to floods is so that communities can consider relocation and be safe, but this is not the case as some residents in affected areas refused to be resettled, and some continue to live in their old homesteads even after new houses were built for them.

The level of awareness on the flood disaster preparedness and response in Tsholotsho District is satisfactory, and much reliance has been on indigenous knowledge which, in some cases, is proving to be harmful to communities. Though awareness campaigns are being held in affected communities, some residents do not attend, and those who do feel that some of the suggestions are fast placing them on the road to cultural dilution and loss of their traditional practices which sustained their forefathers.

Phone text messages and radio are increasingly becoming a viable method of communication, especially when it comes to early warning. However, the problem now is acting on these warnings. Flood disaster statistics, though compiled in a number of government reports, have not been shared or communicated to communities in flood-prone areas, yet communicating these would help foster an understanding of disaster risk. Improved use of phone text messages and social media platforms like WhatsApp, where groups could be formed involving at least one member per household, could facilitate effective dissemination of flood disaster information. Education could be a very important tool because each household sampled had at least two members currently in school, thus providing an opportunity for the community to be taught extensively on flood disaster risk. The presence of non-governmental organisations like World Vision and Plan International, as well as churches and government departments like the President's Office and Agritex, could all provide platforms through which the community could be educated and have its understanding of disaster risk enhanced.

Recommendations

In light of the findings from this research, the following recommendations can be drawn with the aim of improving the communities' level of awareness and subsequently enhancing their understanding of disaster risk and reducing their vulnerability. The researchers recommend that the District Civil Protection Unit enhances the role of indigenous knowledge systems in the district so as to achieve improved disaster risk reduction. To change the communities' perceptions about flood risk, peer-to-peer education should be employed. Flood victims should be given a platform to share their experiences of flood disasters in order to change the perceptions of at-risk communities. Also, in order to foster an understanding of flood disaster risk and change communities' attitudes to flood risk, the Civil Protection Unit should employ extensive use of visuals to help foster an understanding of disaster risk and change communities' attitudes to flood risk, whilst also reaching members of the communities who cannot read. The Disaster Risk Understanding Model (Figure 3) also highlights how the system of governance influences rural communities' understanding of flood risk. A change in governance style would go a long way in Tsholotsho District. This could be done by Disaster Risk Reduction practitioners' engagement with the community through public consultation and collaboration with the community disaster management committees — the top down approach in order to improve communities' understanding of disaster risk. Information that is discussed at village meetings with chiefs should be cascaded down to the villages through the village head (usobhuku) and headman (umlisa). With regard to disaster statistics, the District Civil Protection Unit should make flood disaster statistics available to the community (schools, village meetings), in line with the Sendai Framework for Disaster Risk Reduction, and these should be in local languages — Ndebele and Kalanga for effective communication.

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Chapter **08**

Climate Change and Human Settlements: Towards a Strategic Framework for Sustainable and Resilient Land Use Planning and Practice in Zimbabwe

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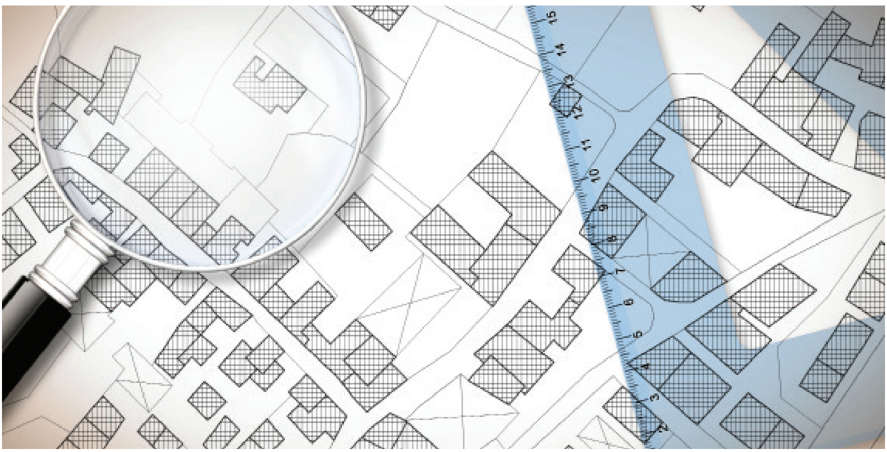

Introduction

It would seem that climate change stands aloof from many human settlement challenges due to its serious negative impacts on human settlements and sustainable urban development. The rate at which natural disasters are increasing has multiplied in the past few decades, (UNISDR, 2012). This poses uncertainties regarding the frequency, depth and magnitude of the hazards, making planning for, and management of the perceived impacts relevant. Urban areas are high risk spots for natural hazards (Pelling, 2004). With the imminent increase in city population and the challenges this provides, humanity is placed at risk as most of these hazards affect settlements (EEA, 2012). However, despite the urgency of action needed, cities are struggling to find effective strategies to develop resilient sustainable solutions towards problems that come with climate change (UNISDR, 2010). Many studies have been undertaken on how climate change has affected human settlements, and how some countries have successfully fought the battle against climate change. However, there is no critical analysis of existing policies and regulatory frameworks to guide the development of sustainable and resilient human settlements in Africa general and Zimbabwe in particular. This has seen a slow response to the impacts of climate change, thereby making the nation vulnerable to future climate change disasters especially if no effective action is taken now.

Zimbabwe borrowed development principles from the colonial regime, and these have been guiding most development standards. However, a gap remains as these policies fail to meet present needs of modern settlements. The bulk of existing policies sound colonial and have not been updated and adapted to provide solid and reliable guidelines for managing urban and rural land use, as well as construction. Aiming to contribute to the existing body of knowledge, this chapter seeks to reveal the relationship between climate change and human settlements so as to provide an appreciation for the need of a strategic framework for sustainable and resilient land use planning, policy and practice in Zimbabwe. There is need for cities to find better strategies to adapt to and mitigate the climate change effects (Wamsler, Brink & Rivera, 2013). This chapter assesses such efforts being put in place globally and regionally, and compares them with Zimbabwe's efforts to provide recommendable solutions. Climate change is a reality that needs urgent action by city managers to curb its effects and develop resilient preventative tools.

Context of the study

Climate change is a global phenomenon, and countries are working on countering its impacts. Most developed countries find it easy to implement climate resilient policies, given that they have plenteous financial and manpower resources. Australia managed to use land use planning in countering climate change effects. Its local councils are mandated to develop land use considerate of the environment and human settlements (Bajracharya, Childs & Hastings, 2011). China also strengthened its fight against climate change through establishing early warning systems and efficient monitoring of disasters. Proactive policies have been taken to mitigate climate change effects (IOSCPRC, 2008). However, the success of climate policies differs spatially as countries encounter different challenges and are at varying levels of development. Overall, climate change is experienced in varying dimensions and magnitudes across the globe. It is therefore important for planning officials and policy makers to contextualise and apply strategies that work for a specific area.

Climate change knows no status and, as such, the vulnerabilities of poor groups to its impacts are worsened (Dodman, 2011). Therefore, when developing policies for climate change adaptation, it is important to consider and appreciate that the extent of vulnerability differs among various population groups. In such circumstances, Zimbabwe managed to embark on pro-poor policies that consider the poor groups of society (Satterthwaite et al., 2007). This helps to bring equity amongst society groups as the marginalised groups get assistance in curbing climate change impacts, although the success of such policies is still questionable. In the Southern Africa region, South Africa is amongst a few countries that have incorporated climate change adaptation strategies in planning. Durban City Council has been working hand in hand with the UK Tyndall Centre for Climate Change Research to develop models that allow for strategic climate and urban planning. (Joshua, Jalloh & Hachionta, 2014). It cannot be dismissed that countries in the southern region are making efforts in the common fight against climate change, though the progress is slow and seems not to be at the core of priorities.

Literature review

A unified fight against climate change impacts reduces "exposure to hazards, lessens vulnerability of people and property, ensures wise management of land and the environment, and improves the preparedness for adverse events" (UNISDR, 2009: 10). The cooperation of the government, local authorities and local residents makes it easy to implement mitigation strategies for climate change. A bottom-up approach is relevant if success is to be achieved. When climate change hazards strike, the local community is the most vulnerable group to feel its detrimental effects and, as such, should be involved in the full processes of planning for, and management of climate change hazards (Wamsler, Brink & Rivera, 2013). Meyer-Ohlendorf (2009) emphasises on the need to coordinate climate mitigation and adaptation strategies with national land use policies to enhance the implementation capacities for local authorities.

The efforts to curb climate change in most African countries in the southern region are biased towards the rural areas rather than cities (Brown et al., 2012). This leads to a high tendency of neglecting the urban areas that are also vulnerable to climate change (Government of Malawi, 2006). However, the success of land-use-climate-change policies is dependent mostly on the financial capacity of the planning authorities, coupled with governance efficiency (Seto, 2014). Apart from financial capability, successful climate change policies require political will backed by the institutional capacity to have effective policies that match well the spatial development strategies (Seto, 2014).

The attainment of independence for Zimbabwe brought changes to the urban structure since 1980, as people started streaming to towns (Mecartney & Connell, 2017). Many changes in land use were experienced that saw much of the land that primarily was agricultural being turned into urban. Urbanisation, together with natural population increase, are the key contributors to a higher concentration of people in urban areas and the resultant encroachment onto marginal areas that are highly vulnerable to natural disasters (Connell, 2018). This has exerted pressure on various resources, thus affecting the livelihoods of citizens through high unemployment rate and inadequate service provision in the form of water and electricity supplies. Exacerbated environmental challenges are intertwined with sewerage and waste management problems that already exist (Connell, 2018). This has affected urban management and, as such, is a cause for concern in urban planning. In addition to the many planning issues, climate change brings impacts that require immediate attention.

Human settlement planning becomes a relevant tool for achieving sustainable development. This is because it plays an important role in building resilience in the face of climate change by creating resilient urban environments through promoting density, diversity and connectivity in urban areas (Abunnasr, 2013). In addition to climate change, other global environmental problems such as loss of biodiversity, water scarcity, and changes in the nitrogen cycle should be included as planning issues (UNHABITAT, 2016). Jiang et al. (2017) argue that cities have a huge obligation and role to play in mitigating climate change. Therefore, it is of importance that planning ensures resilience in human settlements to promote safety in human environments.

Climate change has become a disaster and risk management issue as it poses uncertainties and impacts on the natural and the human environment. Therefore, strategic planning and management have become a necessity in order to create safe and liveable human settlements (Bajracharya, Childs & Hastings, 2011). The absence of common planning and integration in local authority functions has contributed to a divergent gap between disaster and risk management, and land use planning. With the growing concerns on the impacts of climate change, land use planning seems to play a vital role in fighting climate change impacts and ensuring safe human settlements that are resilient (Bajracharya, Childs & Hastings, 2011). With such insights, it is evident that there is an evident relationship between climate change and human settlement planning. Hence, this chapter serves to provide stylised evidence that links land use planning and human settlements (rural and urban) to climate change. The chapter advances the argument that land use planning ought to be double-edged in its approach in that artefacts in human settlements affect and are affected by climate change.

Land use planning is one of the most important policy making and development fields due to its universality in tackling development problems (Shalaby & Aboelnaga, 2017). It embodies various tools that include plan formulation, development planning and management, and the engagement of stakeholders that are relevant to climate change mitigation and adaptation. The engagement of stakeholders enhances the formulation of pro-poor policies that help counter climate change vulnerabilities as the local people are capacitated and become knowledgeable about mitigation measures (Shalaby & Aboelnaga, 2017). However, the complete success of the measures depends on a variety of factors, one of which includes the availability of financial resources and the intervention tools used. Land use planning makes provision for climate change mitigation policies; land management strategies are delivered through integrated adaptation approaches that ensure sustainable development (Yiannakou & Salata, 2017).

The incorporation of climate resilient strategies in the formulation of urban policies should be prioritised in order to attain sustainable development with resilient settlements (UNHABITAT, 2013). As such, urban policies should promote the design of green buildings that lead to a reduction of emissions and retrofitting the already existing buildings to match the required standards. There is a lot that urban planners and other practitioners can do to enhance resilient development. Green buildings as one of the commonest measures include having rooftops that have vegetation and that are designed in a manner that is cost-effective and allows for rain water harvesting (Abunnasr, 2013). This is a measure that can work well against the impacts of drought while, improving the quality of air in the built environment.

Land use planning, though a physical approach, should also incorporate the society and all stakeholders in the process to achieve inclusive policies. In light of that, UNHABITAT (2013) promotes an inclusive approach to land use planning that considers the rights of the citizens and, at the same time, being a participatory action. This means that initiatives to climate change action can start to be implemented at lower-marginalised and remote areas that are mostly vulnerable, and then move up to less endangered areas. There is a need for strictness in the implementation of development policies. A good example given by the UNHABITAT (2013) is that of protecting wetland areas from development and siting human settlements in safer places. However, with the increased shortage of land, coupled with corruption in land management, many people settle in high risk areas (Elsinga et al., 2020). Placing people in safe areas initially, saves on the costs of relocating and compensating people in case of hazards occurring. When developing climate-resilient societies, UNHABITAT (2013) encourages the policy makers to consider the ecosystems and develop decisions that protect and maintain the natural ecosystems through buffers.

Research Methodology

Vulnerability of communities is the greatest threat to human settlements. When disaster strikes an unprepared community, the resultant effects on the community are damaging. Vulnerability to disasters is the extent to which societies or communities are "susceptible to the damaging effects of a hazard" (UNISDR, 2009: 30). In light of that, communities need adequate planning to ensure their safety and preparedness for hazards through proper land use. Thus, the chapter engages literature review to learn and decipher the direction taken by other countries in this regard. It also undertakes document review to examine the existing frameworks. The chapter uses a case study approach to learn from selected local authorities about how they are mainstreaming climate change in their planning, implementation and maintenance of existing infrastructure and superstructures.

To provide a better picture of these processes, two of the case studies are urban (Harare and Mutare), and two are rural (Chikomba and Beitbridge). Building the cases is achieved through key informant interviews, interrogation of existing and planned land uses (with related infrastructures), and analysis of archival data (plans, reports, databases, etc.) These case study areas have been chosen given their peculiarities in population and climatic dynamics. The research used Geographical Information Systems (GIS) and remote sensing to come up with land use and land cover change maps for the studied areas spanning from 1990-2020. Administrative shapefile boundaries were digitised in a GIS environment for Ward 14 of Chikomba and for Ward 1 of Beitbridge districts in projected reference systems. In doing so, satellite images from Landsat series of Landsat 5 and 8 were used respectively, for classification using random forest classifiers in Google Earth Engine. A combination of Landsat 5 and 8 was used despite differences in their spectral bands because Landsat 5 was able to provide the 1990 imagery that is unavailable on Landsat 8 and, again, Landsat 5 is part of the old series that do not provide 2013 up to 2020 images.

Climate change in Zimbabwe

The impact of climate change is mostly felt by the vulnerable and marginalised groups of society. In developing countries such as Zimbabwe, most rural people tend to be more vulnerable to the impacts of climate change. Drought seasons and unreliable rainfall patterns lead to poverty and food deprivation for the rural people who mostly rely on farm activities for their living (Mpambela & Mabvurira, 2017). Droughts and flooding are among the most recurring climate change impacts in Zimbabwe (Connell, 2018). Intermittent rainfall patterns have become very common, and usually where it is considered to have rained, floods are imminent. Mazvimavi (2010) highlights that annual rainfall fell by 100 mm or 10% in the past century which has been characterised by frequent droughts. Droughts have affected even the produce from the fields and have caused hunger in most parts of the country. Droughts lead to the reduction of underground water that, to a greater extent, remains a reliable source of water when rainfall fails. However, a continuous increase in temperature ranges leads to out-sapping of aquifers on which urban areas mostly depend, as there is continued abstraction of water for various uses leading to complete depletion (Mazvimavi, 2010).

Flooding has detrimental effects on societies and human settlements. It leads to the destruction of infrastructure and even to loss of life. On its own, flooding has multiple damaging impacts, such as increased poverty as most of the reliable livelihood sources are destroyed (Connell, 2009). It catalyses the increase in urban population due to rural-urban migration as people move in search of greener pastures and settle for reliable livelihood sources. However, this worsens the already existing urban challenges evidenced by informal settlements owing to the fact that formal housing becomes scarce and expensive. People settle mostly in marginal areas that are themselves also vulnerable (Connell, 2018). This shows that climate change and its impacts are actually a chain of complex problems that can be continuous if no proper policies and management are put in place.

Existing Frameworks and Policies towards Managing Climate Change

Gaps do exist with regards to effective strategies for human settlements against climate change impacts. This makes the fight against climate change impacts ineffective at a time when climate change is accelerating (Connell, 2018). The lack of understanding of the uncertainty in climate change hazards, such as cyclones and droughts, has led to reluctance to act by the policy makers. Much focus is placed on economic development as opposed to environmental management. Such economic pursuit has led to piecemeal climate change policies and weak, inefficient regulations. Urgent action needs to be taken as the severity of climate change continues to worsen, with its impacts and frequency affecting the sustainability of human settlements and also increasing vulnerability (Connell, 2018).

The major climate change policy for the country is the National Climate Policy of 2017 that is supported by the National Climate Change Response Strategy (Government of Zimbabwe, 2020). The policy envisions a resilient carbon-free Zimbabwe through guiding the management of climate change, and also emphasises evidenced-based policy strategies that allow for the participation of the indigenous people. This is supported also by the Environmental Management Act (Chapter 20: 24) which promotes the protection of natural resources to prevent environmental degradation (Government of Zimbabwe, 2020).

Harare harbours many people, and has estimated population of around 2.1 million in the 2012 Census, which may have doubled in the past years (ZIMSTATS, 2012). Brown et al. (2012) state that by 2025, the country will be facing extreme water challenges. This would worsen the vulnerability of humans, particularly in Harare, where there is a higher population than available resources to meet its needs. Because climate is not turning back, it is more important now than later for cities to embark on effective measures and policies that mitigate climate change. Climate change will continue and worsen the already existing urban challenges. Milan (2016) emphasises on the need to improve on urban governance issues so that they do not deter the success of climate change strategies.

The climate change policies that the country uses are pinned mainly on the United Nations Framework Convention on Climate Change (UNFCCC) that was introduced in 1992 (Gutsa, 2014). The nation acknowledges the imminent need for incorporating climate change as part of all development frameworks and policies (Government of Zimbabwe, 1998). However, this has only existed on paper up to around 2012 as there was no policy that targeted climate change issues. Most of the effective measures that are aligned to climate change include natural and environmental management of resources such as water and forestry (Chagutah, 2010). The formulation of legislation and policy frameworks for climate change is very important to protect the most vulnerable and marginalised groups of society (Madzwamuse, 2010). The drawbacks affecting participative policy making have been due to little communicative research that brings together policy makers, researchers and the local people (Jones & Walsh, 2008). To successfully achieve effective climate policy measures, there is need for evidence-based approaches which are enabled through stakeholder participation in policy formulation (Ahmad, 2009).

Various strategies that can be applied to curb the consequences of climate change such as droughts, have been applied sectorially. Such sector-specific strategies when formulated, make every department play a fair role in the fight against climate change challenges (Wamler, Brink & Rivera, 2013). There is a need to promote the cooperation of all stakeholders from the planning to the implementation of the strategies and policies. This enhances capacity building for the lower level community members who are at the firing point. Some inclusive strategies include rainwater harvesting measures that enable water availability in the case of droughts and intermittent rainfall. Urban design brings smart city strategies that are a reliable measure through the construction of green infrastructure that includes facades that can be used in the same manner as windbreaks and rooftops that have vegetal cover. However, integrative measures that accommodate all physical, cultural, political and economic measures are relevant in promoting resilience (Wamler, Brink & Rivera, 2013). To achieve resilient and sustainable cities, it is imperative for planning to encompass all risk factors and to not target the built environment alone.

Climate change needs to be explicitly incorporated in urban policy. However, most policy makers lack evidence-based researches that lead to uniform policies that are evidence-based (Gutsa, 2014). Despite the increasing impacts of climate change, urban and development policy is failing to fully meet the demands of climate change mitigation and adaptation (Brown et al., 2012). This is due to the use of master plans that are outdated and cannot, therefore, meet the ferocity of climate change (Brown et al., 2012). Joshua, Jalloh and Hachinta (2014) reveal that even in the existing plans, climate change and the vulnerability of human settlements are not prioritised or even considered. The responsibility of climate change planning is usually given to higher ministries than the local planning authorities that are able to meet local challenges (Joshua, Jalloh & Hachinta (2014). However, the local authorities lack capacity to drive the climate change mitigation agendas and strategies that make it difficult to achieve sustainable climate change mitigation strategies.

Table 8.1: A Summary of the Existing Policy and Legal Frameworks for Climate Change in Zimbabwe

Name of Policy/ Statute	Key Issues for Human Settlement	Relation to Climate Change	Missing links
National Climate Policy (2017)	No substantial inclusion of land use planning	Climate-resilient and low carbon nation	Indigenous knowledge from public participation
National Climate Change Response Strategy	Targets sustainable development, climate-resilient nation	Management and utilisation of water sources	Land use planning and human settlements against climate change
National Capacity Self-assessment for Climate Change (2006)	There is no involvement of specific land use planning notions.	Incentives for climate-responsible citizens	No communication, centralised information
Constitution of Zimbabwe	Human right to safe environment	Prevention of ecological degradation	Land use planning and human settlements against climate change

Nationally-determined Contribution (2016)	Lack of mitigation plans that narrow down to local authorities' capacity to implement climate policies	- Management of water sources - Resilient management of climate-related risks	- No intensive research - Land use planning and human settlements against climate change
Zimbabwe National Agriculture Policy Framework (2018-2030)	Sectorially specific policy with less integration of land use planning	- Climate-resilient agriculture practices - Low-cost climate smart technology	- Research practice gap - Land use planning and human settlements against climate change
Transitional Stabilisation Programme (2018-2020)	Sectorially specific policy with less integration of land use planning	Environmental management	Land use planning and human settlements against climate change
Environmental Management Act (Chapter 20:24)	Not harmonised with planning policies and legislation.	Sustainable management of natural resources and environmental protection	Land use planning and human settlements against climate change
The National Environmental Policy and Strategies (2009)	Generalised and lack planning specific notions that target human settlements.	Environmental education and awareness	Land use planning and human settlements against climate change
Meteorological Services Act	Capacity building	Education and training	Land use planning and human settlements against climate change
Low Greenhouse Gases Emission on Development Strategy (2020-2030)	Narrowed towards Air pollution and little to do with land use planning.	Climate change mitigation analyses	Land use planning and human settlements against climate change

Source: Government of Zimbabwe (2020)

Table 8.1 provides a summary of the legal and institutional framework for climate change in Zimbabwe. Various instruments are in place that are aligned towards the management of climate change. The listed policies and legislation on environmental management and climate change need to be integrated into land use planning to create climate-smart human settlements. The table indicates that the human settlements factor in the context of climate planning has not been incorporated.

Human settlements suffer direly when not carefully planned for against climate change impacts. The legislation that exists, for example, the Environmental Management Act (Chapter 20:24), highlights general notions in maintaining smart environments such as capacity building which is common in most of the policies. However, there has not been a significant appreciation of the importance of climate planning. There are research-practice gaps and lack of climate change awareness in most settlements. The policies, as highlighted in the table, are not harmonised in land-use planning, and this renders climate change adaptation strategies and efforts futile, especially in human settlements.

Case Studies

The study made use of four case studies to concretise the arguments put forward using the situation on the ground. Harare, Mutare, Chikomba and Beitbridge were selected as case studies, with the urban areas represented by Harare and Mutare cities, and the rural areas by Beitbridge and Chikomba districts.

Harare

Apart from being the capital city of Zimbabwe, Harare is also the largest city in the country. Rapid urbanisation and population growth increase in the Harare Metropolitan Province has led to massive usage of land that has caused encroachment of marginal rural areas, (Marondedze & Schutt, 2019). ZIMSTATS (2012) indicates an increase in population for the city that hovered around 2.1 million from approximately 1.5 million in 2002 (Marondedze & Schutt, 2019). Such expansion in urban population has also led to an expansion in the built environment that Marondedze and Schutt (2019) highlight to have moved from 279.5km2 in 1984 to about 445km2 in 2018.

The increase in urban population, coupled with the expansion of the built-up area, can be appreciated in Figure 1 showing land use land cover change (LULC) for Harare since 1990 till the present scenario on a 15-year interval. This has led to the expansion of the city built-up area as seen through the city's encroachment of other areas beyond its jurisdiction, as well as shrinking vegetal cover. Dube and Chirisa (2012) reveal the rising housing challenges for the city as its resources have been outgrown by the needs of the residents. With the existing evidence implying a further increase in the population of the city, it is important for the city to make futuristic plans that will cater for the population demands and reduce the vulnerability of citizens to climate change impacts. Marondedze and Schutt (2019) explain the climatic conditions of Harare as being sub-tropical associated with varying winter-summer seasons, with evident climate change effects. The city faces challenges in service provision as most of its efforts are interfered with by politics (Dominguez Torrez, 2012).

If the population continues to increase, coupled with the impact of climate change, more service challenges such as water stress, will be felt. This will also affect the livelihoods of the people who mainly rely on informal sector activities like vending, illegal money changing and urban farming. There is need therefore for effective policy measures and frameworks that help citizens to cope with climate change effects. Muchadenyika and Williams (2017) highlight that there is poor policy formulation and planning for the city by the council such that there are no long-term plans that govern the management of the city. This is attributed to lack of resources, such as finance, to implement budgeted services, leading to a continuous cycle of urban challenges. The city relies mostly on the government's National Climate Policy of 2017, together with the Environmental Management Act (Chapter 20:24) that enables the fight against environmental degradation (Government of Zimbabwe, 2020). Therefore, if the battle against climate change is to be won, there is a need for cities to stand on their own and plan for resilience and safety, thereby reducing vulnerability.

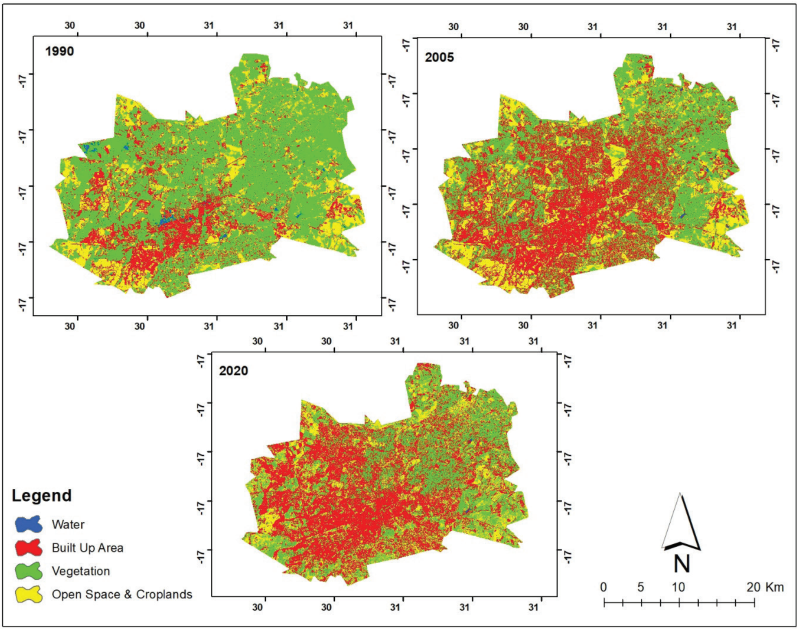

Figure 8.1: LULC for Harare from 1990 to 2020

From the Land Use and Land Cover (LULC) map in Figure 8.1, it can be clearly noted that the city experienced a change and a loss of area covered by vegetation and open space, thus indicating a massive land use conversion to built-up areas over time (Marondedze & Schütt, 2019). A summarised overview of the statistics of changes in area over time for Harare can be visualised in the form of a table

Table 8.2: Summary of Statistics for Harare 1990 and 2020

Class	Harare 1990		Harare 2020		Percentage Changes
	Area (ha)	Percentage (%)	Area (ha)	Percentage (%)	%
Water	412. 0279937	1	124.1907718	0.18	0.82
Built-up Area	12796. 46736	19	29945.7054	45	-3.67
Vegetation	40539. 81078	61	24199.32718	36.6	0.4
Open Space and Crop-lands	12282. 07932	19	11762.31997	18	0.05
Total	66 030.3854537	100	66031.5433218	100	

Mutare

Mutare is expanding at a tremendous growth rate though the expansion is limited by its mountainous geographical terrain (PRFT, 2011). It is the border city to Mozambique with an approximate population of 170 000 as of 2002 (PRFT, 2011), and this has increased to about 1.75 million as of 2012 (ZIMSTATS, 2012). The population growth has been gradually increasing since the attainment of independence (Munzwa & Jonga, 2010). The majority of the population relies on urban agriculture, with some depending on the support of non-governmental organisations (Gwetsayi, Dube & Mushapa, 2016). Urban challenges are nearly the same in the cities, with differences according to city size and population. Mutare is not excluded from common urban challenges like sprawling. Chikodzwe et al. (2019) highlight that Mutare's mountainous geographical terrain restricts urban expansion, even in the face of the continuous urbanisation experienced in the city. The terrain affects the provision of services for the city, thus exacerbating urban challenges constrained by inadequate land (Chikodzwe et al., 2019).

Mutare also relies on the nation's climate change policies and other law instruments such as the Environmental Management Act, to slow down climate change impacts (Government of Zimbabwe, 2020). Climate change mainstreaming in the city oscillates around existing government policies. Not much has been done by the city to plan for climate change policies as it is incapacitated to formulate workable climate adaptation policies. Chikwature and Chikwature (2019) further reveal the service provision challenges that the city is facing and how this has been evidenced by the pollution of natural water sources, such as Sakubva River, from inefficient sewer systems (Chikodzwe et al., 2019). There is a need for the national government to work together with city municipalities to fight climate change and urban challenges. Most of the urban councils are incapacitated to deal with climate change on their own, and thus state rescue is imperative. Since 1990, Mutare has also experienced a massive land use conversion mainly to built-up areas. Indigenous forest and open space in and around the city have been converted to built-up areas over the same period as confirmed by Table 8.3.

Table 8.3: Summary of statistics for Mutare 1990 and 2020

Class	Mutare 1990		Mutare 2020		Percentage Changes
	Area (ha)	Percentage (%)	Area (ha)	Percentage (%)	%
Built-up Area	4574.62855	24	11415.48035	60	1.5
Vegetation	13001.91487	68	6976.832734	36	0.47
Open Space and Crop-lands	1526.614726	8	709.1611095	4	0.5
Total	19103.15815	100	19101.47419	100	

From the statistics and as well from the map, it can be noted that the area currently classified under vegetation has decreased slightly compared to the same area in 1990. However, the area under the built environment continued to increase from 1990 up to the present situation.

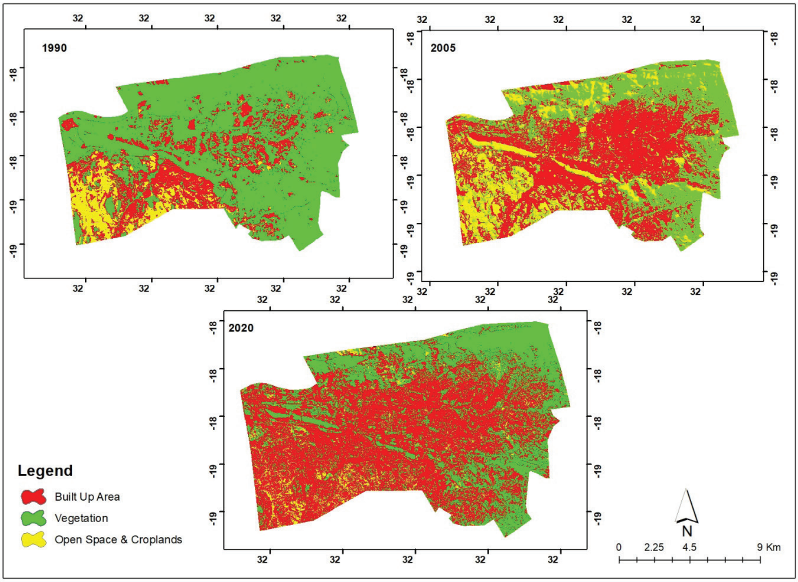

Figure 8.2: LULC of Mutare from 1990 to 2020

Chikomba

Chikomba is an administrative district in Mashonaland East Province with a population of around 12 958 according to ZIMSTATS (2012). Within the district, the research narrowed down and concentrated on Ward 1 in which LULC maps for the period 1990-2020 were created. The results from the LULC maps in Figure 8.3 show a massive conversion of land use from vegetation to croplands over the same period. Due to low spatial resolution of Landsat images, rural spaced homesteads were not classified as part of the map. Chikomba is an agro-ecological rural district characterised by high temperatures that often result in droughts and poor rainfall (Mutasa, 2011). Gutsa (2014) highlights that the district relies on agriculture in the form of cattle rearing for livelihoods. The rural district council works hand in hand with communities to mitigate and adapt to the effects of climate change in the region. Various ways to adapt to hunger and food shortages resulting from droughts include the gathering of fruits and the trading off of cattle for food (Mutasa, 2011). The district also relies on the enforcement of environmental legislation to prevent environmental degradation (Government of Zimbabwe, 2020). However, local efforts at climate change adaptation are unreliable and demand immediate policy action to establish long-lasting resilient solutions (Mutasa, 2011).

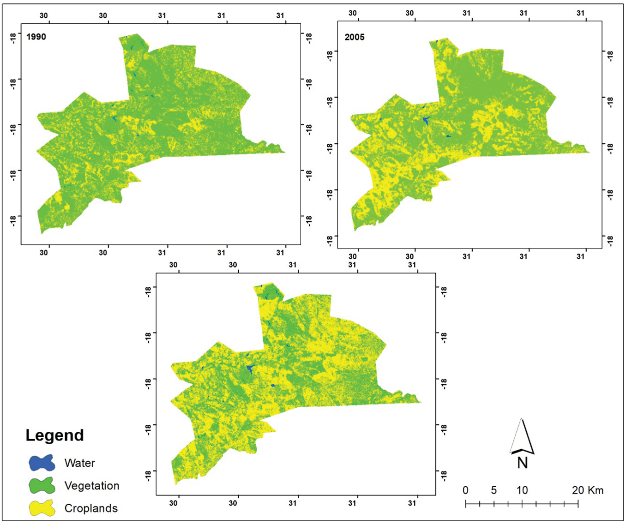

Figure 8.3: LULC of Ward 1 of Chikomba District

An increase in population over time has exerted pressure on natural resources within the area, resulting in more land being converted from vegetation to croplands. In 1990, croplands occupied approximately 37% of the total area, and this marginally increased to 58.63% in 2020. Currently, due to increasing pressure on agricultural land, croplands occupy an estimated area of 37680.2487, about 58.64% of the total area of Ward 1. The LULC statistics for Ward 1 for 1990 and 2020 are summarised in Table 8.4.

Table 8.4: Summary of Statistics for Chikomba Ward 1 from 1990 and 2020

Class	Chikomba 1990		Chikomba 2020		Percentage Changes
	Area (ha)	Percentage (%)	Area (ha)	Percentage (%)	%
Water	12.00859515	0.018	231.9243447	0.36	-19
Vegetation	40215.49744	62.58	26345.63939	41	0.34
Croplands	24029.71475	37	37680.2487	58.64	-0.58
Total	64257.22078515	100	64257.8124347	100	

Beitbridge

Beitbridge is Zimbabwe's busiest border town to South Africa (Chitekwe & Mitlin, 2001), with a population of approximately 42 218 as of 2012 (ZIMSTATS, 2012). The urban centre was founded in 1929 according to Chanza et al. (2017). Its land coverage is estimated to be around 12 697 km2 (UNEP, 2007). Of the 12 697 km2 of the district, 577 km2 fall under Ward 14 of the district that the research paid much attention to. Due to the strategic position of the district, the population has continued to increase as people stream in from other places to access livelihood opportunities presented by the border town. This growth and expansion have seen housing development improving from the "plastic shacks" of the 1990s to modern formal housing (Chitekwe & Mitlin, 2001). Despite the perceived opportunities for the town, the municipality's capacity to provide services has been overwhelmed (Chanza et al., 2017). The continuous flow of sewer and infrequent water supplies are evidence of the poor capacity of the municipality (WSP, 2014).

The district is characterised by very high temperatures and erratic rainfall patterns that have affected most agricultural activities. Matsa and Dzawanda (2019) denote that high temperatures, unpredictable rainfall patterns together with other climate change impacts, have adversely affected the district's indigenous farmers who are now relying on the support of non-governmental organisations for their livelihoods. Just like other districts in Zimbabwe, not much has been done by the town to fight climate change impacts. More reliance is placed upon the government's actions and by-laws (Government of Zimbabwe, 2020). One of the well-noted climate actions that has been done is the cooperation between the councils of Beitbridge and Musina (a town 10 km away in South Africa) with regards to the management of natural resources and disaster management, giving particular attention to the Limpopo River (UNEP, 2007). Being already in a vulnerable climatic state, there is a need for urgent action to curb climate change effects that can worsen and affect the livelihoods of the people in the district.

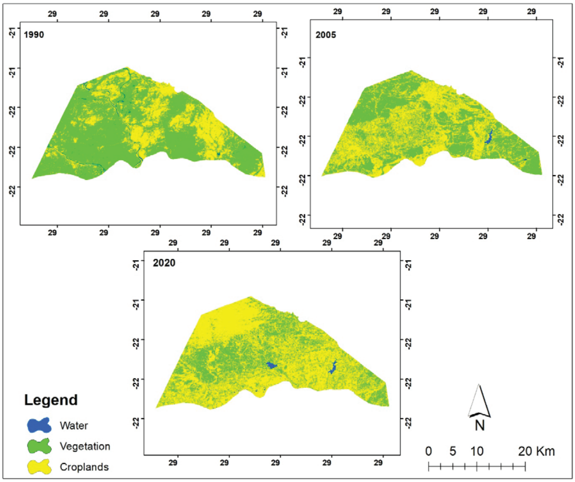

Figure 8.4: LULC for Beitbridge Ward 14 from 1990-2020

The increasing demand of agricultural land has led to massive loss of vegetation from 1990 till present, with cropped land increasing from 37% in 1990 to about 67% of the total ward area in 2020. Agricultural activities within the area were enhanced by the construction of another major dam within the ward, as seen from the summary in Table 8.4.

Table 8.4: Summary of Statistics for Beitbridge Ward 14 from 1990 and 2020

Class	Beitbridge 1990		Beitbridge Ward 14 2020		Percentage Changes
	Area (ha)	Percentage (%)	Area (ha)	Percentage (%)	%
Water	525.2563584	1	569.5923112	1	0
Vegetation	39987.47689	69	18587.69658	32	0.54
Croplands	17213.28389	30	38565.84117	67	-1.2
Total	57726.01715	100	57723.13006	100	

Discussion

With climate change driving many people from the rural areas, the urban landscape of Zimbabwe is gradually increasing (ICED, 2017). Nyoni and Bonga (2017) reveal that the urban population in the country is set to increase, assuming the current conditions remain the same. Since 1980 when the country attained its independence, population growth has been rapidly increasing as people continue to seek greener pastures in the urban centres (Aghimien, Algbavboa & Ngwari, 2019). Patel (1988) also asserts that with independence and de-racialisation, more people moved to urban areas. This has affected the local authorities in terms of service provision as their capacity has been outpaced by the increase in population. Some efforts have been made in trying to meet such challenges, and these include policies to reduce housing shortages by the Ministry of National Housing and Social Amenities (Ministry of National Housing and Social Amenities, 2012). However, despite these efforts, the nation still struggles to provide adequate housing (Muchadenyika, 2015). Major setbacks have been as a result of poor and outdated policy frameworks and lack of budget prioritisation (Aghimien, Algbavboa & Ngwari, 2019).

Climate change has been affecting most parts of the country as seen from erratic rainfall patterns and droughts that are becoming more frequent and also causing severe food shortages. (Matsa & Dzawanda, 2019). The mitigation and adaptation policies that the country has been applying lean mainly on the United Nations Framework Convention on Climate Change (UNFCCC) that was introduced in 1992 (Gutsa, 2014). The nation acknowledges the imminent need for incorporating climate change as part of all development frameworks and policies (Government of Zimbabwe, 1998). However, this only existed on paper up to around 2012 as there was no policy that targeted climate change issues. It is evident that land use and land cover change have not been accompanied by any local authority efforts at putting climate adaptation and mitigation measures in place. Thus, there has been no climate planning, and much of the problems arise from the gap between national climate policy and its operationalisation by local authorities that lack capacity for climate planning. A realisation of where lies the problem of climate policy formulation and implementation in the country helps the decision makers to tackle the root of the matter and thus enhance the development of more climate-wise decisions.

Most of the effective measures that are aligned to climate change include natural and environmental management of resources, such as water and forestry (Chagutah, 2010). The formulation of legislation and policy frameworks for climate change is very important to protect the most vulnerable and marginalised groups of society (Madzwamuse, 2010). However, most of the existing policies, if not all, are sectorial, which leaves local authorities with less action towards climate change in planning human settlements. A good example of the existing policies and legislative framework include the Environmental Management Act (Chapter 20: 24) aligned to the Ministry of Environment, Water and Climate. This means that a reluctance to act on the part of local authorities in formulating settlement-related climate and environment policies will compromise the resilience of human settlements. Relying on sectorially-biased climate change policies will generalise results and overlook important human settlement aspects.

Both literature and case evidence indicate a number of interesting policy and practical dimensions on the subject at hand. It is observed that the gaps in the existing frameworks are explained by the fragmentation of policy actors, as well as resource constraints, also partly explained by prioritisation. Besides, the political will to push the agenda is usually absent to really make things work. The worsening and high uncertainty of climate change impacts has led to the need to relook at the efforts being made to fight the perceived dangers. New and effective strategies are now required to attain sustainable development amidst climate change dangers. It calls for environmental management bodies to work hand in hand with planning practitioners to achieve long-lasting resilient solutions. There is a need for strategic planning that encompasses all important factors such as community values and political and physical demands (UNHABITAT, 2014).

Conclusion and Recommendations

Climate change is a real land use planning issue that is there to stay, and what practitioners can best do is to formulate adaptive and mitigation measures that enhance the safety and security of humanity and its settlements. It is imperative to make futuristic plans and be prepared for any perceived disasters, rather than experience the cost of correcting problems that could have been avoided. There is a need for a middle-of-the-road model and framework that capacitates local authorities to be able to fight climate change on their own without relying on government policies. The case studies presented in this chapter have indicated the reluctance by the cities to orchestrate their own strategies against climate change. In such a case, capacity building for the authorities becomes imperative. In addition, spatial plans by local authorities need to speak to financial plans so that aspirations are achieved in time and for the different purposes in land use as spelt out in the plans. Efforts to assess the present vulnerabilities and future dangers need to be done to identify effective intervention measures. Local communities need to be well-educated on the dangers of climate change and be capacitated to adapt.

Land use planning is key to influencing the mitigation and prevention of natural disasters by way of formulation of specific land use plans and assessing development inquiries and applications based on the formulated plans. A critical analysis of existing policies and regulatory frameworks is more relevant now than before to guide the development of sustainable and resilient human settlements amidst the climate change peril. The bulk of the existing policies sound colonial and need to be updated and adapted to provide solid and reliable guidelines for managing human settlements. There is an undeniable relationship between climate change and human settlements. Therefore, it is recommended that a strategic framework for sustainable and resilient land use planning, policy and practice in Zimbabwe be formulated in favour of sustainable, climate-smart human settlements. There is need for cities to find better strategies to adapt and mitigate the climate change impacts, and it is high time that land use planning in Zimbabwe grasped resilient approaches to climate planning. To win in the fight against climate change impacts requires a comprehensive and inclusive response through enhancing resilient and adaptive development.

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Chapter **09**

CLIMATE CHANGE ADAPTATION AND MITIGATION OPTIONS IN ZIMBABWE: INSIGHTS FROM THE CASES STUDIES

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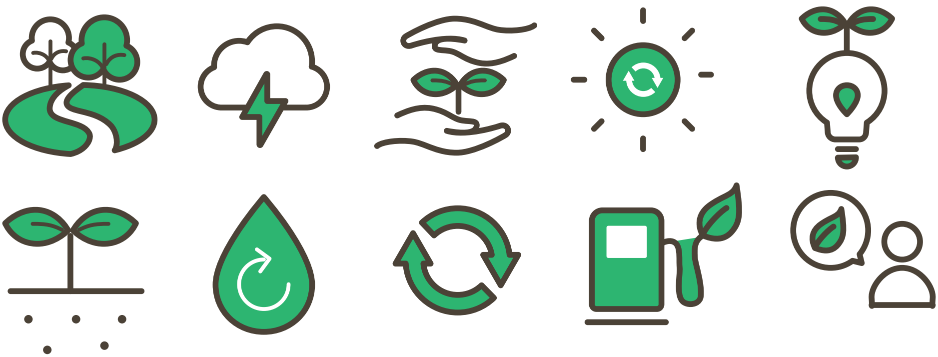

Introduction

Climate change is a reality that not only poses great challenges to human life, but also threatens biodiversity. It is adversely affecting agricultural systems, ecosystem services, water supply and food security, mostly in developing countries (Komba & Muchapondwa, 2018; IPCC, 2014). The main cause of climate change is greenhouse gas (GHG) emissions from fossil fuel combustion (Muhati et al., 2018; IPCC, 2007) and agricultural practices (Brown et al., 2012; Edwards-Jones et al., 2009). Efforts to mitigate climate change have been directed towards reducing atmospheric carbon concentration either by reducing the sources of these gases (for example, substituting burning of fossil fuel with electricity) or enhancing the sinks that accumulate and store these gases such as forest and soils. Scholars argue that it is important to reduce vulnerability to the harmful effects of climate change, such as extreme weather events or food insecurity through adaptation (Adego et al., 2019; Di Falco & Veronesi, 2018; Khanal et al., 2018). Although climate change poses a great challenge to humans, people should make the most of any potential beneficial opportunities associated with climate change, for example, diversify into crops and livestock that are drought and disease tolerant. However, mitigation and adaptation are not mutually exclusive approaches. Mitigation strategies that require that communities preserve forests have the potential of depriving them of their livelihood. On the other hand, adaptation strategies may increase the production of greenhouse gases. This chapter summarises key findings from the preceding chapters and provides suggestions of strategies for improving climate change mitigation that are human-friendly, and adaptation strategies that are climate-smart.

Summary of findings

In Chapter 2, Mabaso et al. assess the level of adherence of urban planning practice to Green Infrastructure principles. Results showed that Green Infrastructure can be implemented at multiple (macro-, meso- and micro-) planning levels. Masvingo City uses a master plan at the macro planning level, and the plan managed to pre-identify ecologically-significant areas (river buffers and nature reserves) in advance of town development. There is also a significant integration of green and grey infrastructure in Masvingo City. The integration is in the form of buffer zones and servitudes of major infrastructure, as well as trees along streets and on individual properties. The level of connectivity is greatly compromised by the uneven spatial distribution of the green spaces across the landscape, despite being physically connected by river buffer zones. The findings also show significant protection of ecologically-sensitive areas (wetlands and river banks) from urban development apart from minor encroachments by housing developments. However, open spaces in the city, including wetlands and natural water courses, are under threat from informal urban agriculture and deforestation, which has led to the degradation of the green spaces. The degradation and low connectivity of green spaces have adverse effects on the capacity of Green Infrastructure to act as an urban resilience strategy in the face of climate change-induced risks.

In Chapter 3, Mataruse, Nyikahadzoi and Fallot show that forest cover has been gradually decreasing over 30 years in three wards in Murehwa District, while crop land was increasing in all three wards. Institutional arrangements designed to ensure sustainable utilisation of the forests include traditional leadership and co-management arrangements between EMA and local communities. Poverty driven responses to climate change, however, have forced villagers to disregard EMA and local leaders' forest management regulations designed to support healthy forests. Chief restraining forces include the need to meet household income demands, firewood and the conversion of forests into crop land. The threats on forests are further worsened by the failure of forests to regenerate naturally due to climate change-induced low rainfall and the growth of invasive species.

In Chapter 4 Mudzengi et al. show that generally there has been an increase in livestock production in Chivi over the past 30 years despite the changing climate. Forty-year temperature and rainfall data shows that temperature was increasing while precipitation showed a declining trend, indicating a decrease in the amount of rainfall received. In addition, key informants also highlighted increases in the frequency of mid-season dry spells and drought events. As a result, there is a long-term decline in vegetation production. This has negative impacts on livestock production and productivity through effects on the quality and availability of feeds and water and heat stress. The results also show that livestock affects climate change through GHG emissions from manure, feed production, environmental pollution, overgrazing and biodiversity destruction. To combat the effects of climate change, and hence address feed, water, and veterinary requirements, livestock farmers have developed coping mechanisms such as supplementary feeding, the use of ethnoveterinary medicines, cattle relocation to areas with better pastures during the dry season, readoption of indigenous breeds, and destocking. These mechanisms are influenced by factors such as resource availability and indigenous knowledge systems. In addition to these coping mechanisms, the study also recommends strategies such as the use of cactus and other browse trees, the establishment of fodder banks, and rangeland rehabilitation.

In Chapter 5, Zvomuya and Mundau use a case study of maize farmers in Gokwe to illustrate climate change strategies for rural livelihoods and social protection in Zimbabwe. Chapter 5 shows that 72.7% of the respondents confirmed that they experienced a decline in harvests over the past 10 years due to climate change. The findings also show that 76.61% of the respondents reduced the number of meals that they were taking per day. Some of the responses to the effects of climate change included participation in food security programmes, participating in the Pfumvudza farming programme, climate change awareness, use of drought-tolerant seeds and the selling of livestock in order to avert the effects of climate change.

In Chapter 6, Mwera et al. discuss the community knowledge of climate change impacts on riparian ecosystem services using a case study of rural communities living along the Mwenezi River in Chiredzi District. The chapter shows that there is a monotonic trend in maximum temperature, a significant decrease in minimum temperature, and a decrease in rainfall. The chapter also notes that the onset of rainfall has shifted from September to early February, and cyclones are now a common phenomenon in the district. The chapter shows that communities depending on riparian ecosystem goods and services such as clean water, wood, fruits and fish for survival noted a downward decline in the availability of these goods and services from the riparian zone. The authors attributed the decline to the effects of climate change. The chapter also notes that the riparian zone provides cultural services to communities for spiritual enrichment and mental development. However, its use for cultural purposes is decreasing due to the increase in Christianity dynamism and the seasonal drying up of some of the sacred pools.

In Chapter 7, using Tsholotsho District as a case study, Sibanda et al., set out to analyse rural communities' understanding of flood disasters in line with the Sendai Framework for Disaster Risk Reduction: 2015-2030. The study shows that 50% of the respondents perceive hazard risks using their indigenous knowledge and also based on their past experience. Study findings also show that community meetings with the CPU are also an important source of information on disaster risks. The detailed analysis of the clouds, water levels in the River Gwayi, vegetation signs and animal behaviour have been pivotal in flood prediction in Tsholotsho District. Following the Cyclone Dineo disaster in 2017, 859 people were resettled in Tshino and Sawudweni where new houses were built for them. Results also show that 33% of the respondents do not stay permanently at these new homes, but instead, they take turns as family members to go to their old homesteads because such homesteads are culturally recognised as their home. Also, families go back to their old homesteads in order to earn a living through farming. When considering the dissemination of Cyclone Dineo disaster statistics, the results indicate that a very significant portion of the respondents (90%) did not have any of the flood disaster statistics communicated to them though a number of government reports were compiled about the disaster .

In Chapter 8, Mazanhi, Nyamugadza and Chirisa show that rapid urbanisation in Harare and Mutare led to massive usage of land, leading to encroachment into marginal areas and shrinkage of vegetal cover. Not much has been done to plan for climate change policies. The study reveals that climate policies and strategies atr not inclusive of land use planning. The impact of climate change is mostly felt by the vulnerable and marginalised groups of society. Drought seasons and unreliable rainfall patterns lead to poverty and food deprivation for the rural people who mostly rely on farm activities. Droughts and flooding are recurring climate change impacts in Zimbabwe. The lack of understanding of the uncertainty in climate change hazards, such as cyclones and droughts, has led to reluctance to act by the policy makers. Much focus is placed on economic development at the expense of environmental management. Such economic pursuit has led to piecemeal climate change policies and weak, inefficient regulations. Despite the increasing impacts of climate change, urban and development policy is failing to fully meet the demands of climate change mitigation and adaptation. Major setbacks have been as a result of poor and outdated policy frameworks and lack of budget prioritisation. It is evident that land use and land cover change has not been accompanied by local authority efforts to put climate control measures in place. Much of the problems arise from the gap between national climate policy and its operationalisation by local authorities that lack the capacity for climate planning. Most of the existing policies, if not all, are sectorial, which leaves local authorities with less action towards climate change in planning human settlements. Relying on sector-biased climate policies tends to overlook important human settlement aspects.

Strategies for improving adaptation and climate mitigation

Climate change has multiple impacts on human wellbeing and biodiversity.

Minimising the Impact of Climate Change on Human Wellbeing

Studies in this book have shown that persistent droughts caused by climate change have resulted in reduced agricultural yields (Zvomuya & Mundau) and health impacts in cities due to heat (Mabaso et al.). Climate change has resulted in flooding in some low lying areas of Zimbabwe (Mabaso et al., Sibanda et al.). The chapter by Mazanhi, Nyamugadza and Chirisa has shown that climate change has caused multiple challenges in urban areas. These include flooding of human settlements, which in turn leads to the destruction of infrastructure, loss of life, increased poverty as most of the reliable livelihood sources are destroyed, and water stress as a result of long-term trends in decreased precipitation or reduced river flows. The chapters in this book demonstrate that climate change has multiple effects in any given community, and therefore calls for a multi-stakeholder approach. To build resilient communities, it is important to adopt a multi-stakeholder and multi-sectorial approach and synergise the efforts and bring together the action of a wide range of government ministries and development partners without denigration of indigenous knowledge systems. Sibanda et al. have shown how locals are using indigenous knowledge to predict weather patterns.

Minimising the Impact of Climate Change on Ecosystem Health

Climate change has multiple impacts on biodiversity. Chapters in this book show that climate change has resulted in insect, pests and invasive species outbreaks (Mudzengi et al.; Mataruse et al,). Mataruse, Nyikahadzoi and Fallot show that climate change is causing the destruction of forests. The invasive species, *Lantana camara*, has encroached into forests and is threatening forest regeneration. Mwera et al., report that communities are experiencing a change in the ability of the riparian ecosystem to provide ecosystem services. Mudzengi et al. and Mazanhi, Nyamugadza and Chirisa have shown that climate change has affected vegetation in dry regions and in urban areas. What is needed is an understanding of critical ecosystem interactions in the context of climate change undertaken by a multi-disciplinary network of researchers.

Improving Adaptation to Climate Change

In many circumstances, while trying to adapt, communities end up causing harm to the natural environment. The study by Mataruse et al. shows that when farmers are threatened by food insecurity caused by persistent drought, they adapt using practices that threaten the health of a forest. As the population continues to increase, the available land share per capita decreases, thus forcing more and more people into opening up forest areas. This includes turning forests into agricultural land for extensive crop production. Some diversify into income-generating projects such as brick moulding and gardening; however, this promotes the rampant cutting down of trees. Strategies that focus on the health of forestry without taking into account emerging competing interest are inappropriate.

In some instances, adaptation has become burdensome for some groups of people. The study by Zvomuya and Mandau has shown how some of the adaptation strategies being promoted by the government such as Pfumvudza are not suited for labour-constrained households, particularly female-headed households that do not have the labour required to adopt labour-intensive technologies such as conservation farming.

Mabaso et al. have shown that there has been a significant shift towards livestock-based livelihood in semi-arid areas as a coping strategy to diversify from crop production, which over the years has been threatened by persistent droughts. In Zimbabwe, there has been a massive drive to promote small livestock as a climate change adaptation strategy (Phiri et al., 2020; Gukurume, 2013). These approaches overlook the fact that livestock contributes to anthropogenic GHG emissions, which consequently affects climate change. Livestock also causes land degradation. The interaction between climate change and livestock production needs to be well understood in order to craft policies and strategies of supporting livestock production in the face of climate change without necessarily increasing emission of greenhouse gasses and destroying the natural environment. We recommend scale-specific, and multi-disciplinary research into climate change adaptation and mitigation strategies to improve the nexus between livestock production and climate change.

Supporting Climate Mitigation in Urban Areas

As the climate is continuously changing, there is need for innovative strategies of adapting to the effects of climate change and adopting climate mitigation strategies. Comprehensive urban forest planning can influence everyday lives of urban dwellers by reducing stormwater runoff and urban heat island temperatures, and maintaining biodiversity (Nowak & Dwyer, 2013). The study by Mabaso et al. has shown that urban trees have the ability to sequester atmospheric carbon dioxide (CO^2) and serve as long-term carbon sinks. The authors have shown that although urban authorities have plans to increase green infrastructure , there are no deliberate efforts to leap into climate mitigation claims and calculations. The planning of urban areas does not seriously take climate change into account. This makes the fight against climate change impacts ineffective, yet climate change is accelerating. Mabaso et al. show how city authorities are trivialising the designing of green infrastructure as a climate change adaptation and mitigation strategy. We challenge local authorities to manage urban forestry to improve upon the benefits of carbon sequestration and storage and other climate benefits provided by trees.

There is need to provide incentives to city dwellers to plant trees. This can be done in collaboration with the Forestry Commission and NGOs. Such incentives may include a reduction in rates for residents who plant and maintain trees in their homesteads and along streets. Local authorities can support the edible Green Infrastructure in the form of urban forests. This will address a range of problems caused by rapid and unplanned urban growth such as food insecurity, poverty, deterioration of human health and biodiversity loss. Urban food forestry can involve a combination of agriculture and agroforestry.

Urban councils should train staff and establish networks with local universities for monitoring and assessing urban forest health. Aspects to be monitored should include but not limited to, the following:

- Long-term change in the urban forest to:
- Understand and manage factors that alter urban forests to help sustain long-term forest health;
- Monitor/Evaluate the effectiveness of local authorities' urban trees programmes and accomplishments;

- Identify critical resource needs for urban forest.
- Ecosystem services and values (air pollution removal, carbon storage and sequestration, building energy conservation).

Promoting Climate Mitigation in Communal Areas

Forests have the potential to sequestrate carbon. In the past forest held in common were well managed by certain well-defined communities with institutions regulating their use. However, climate change has brought in new challenges. Mataruse, et al. Study has shown that recurrent droughts and communities' low adaptive capacity, as well as the presence of multiple stressors such as endemic poverty, and a series of poor harvests, have all contributed to increasing levels of vulnerability and acute food insecurity. This has resulted in the rampant cutting down of trees for fencing vegetable gardens, curing tobacco and fuelwood (which is the major source of energy). The study has also shown that persistent droughts have resulted in the reduction in soil moisture which has resulted in drying up of trees at an alarming rate. The authors also note that climate change has resulted in the growth of some invasive species that are threatening the health of the forests. Local community institutions are not well equipped to manage forests under ever-changing climatic conditions. This calls for innovative strategies of managing the forests, which provide habitat for other wildlife and also serve as a carbon sink.

First, there is a need to educate communities on the importance of the forests as a climate change mitigation strategy, and also reward them for being good stewards of the forest. To achieve this, government and its development partners, including academic institutions, can assist communities to be part of 'Reducing Emissions from Deforestations and Forest Degradation' (REDD+) initiatives and establish partnerships between investors and communities so that they pay forest owners for keeping their forests intact and reward them for the reduction in greenhouse gas emission. This initiative provides an incentive for communities to prevent deforestation and promote afforestation through carbon sale.

Secondly, EMA, the Forest Commission and development partners should leverage the efforts of traditional leaders and local leaders (who already are involved in enforcing by-laws to protect forest) to craft adaptive forest management systems. This should also involve local participation in monitoring and assessing changes in the forests and include non-timber products that are supported by the forests. Under this arrangement, instead of the Forest Commission supplying tree seedlings, it should concentrate on building the capacity of communities in nursery production, tree establishment and management. This is likely to achieve large-scale impacts on climate change, land restoration and livelihood security. Lastly, there is need to reduce communities' dependence on forests for firewood. It is therefore important to reduce smallholders' reliance on natural resources through the promotion of alternative sources of firewood, which include encouraging the use of efficient cooking stoves and biogas.

Crafting Policies Necessary for Effective Climate Change Mitigation

Mazanhi, et al. observe that at the national level, most of the existing policies, if not all, are sectorial, which leaves local authorities with less action towards climate change in planning human settlements. They further argue that the challenge with urban planning is the lack of collaborative research that brings together policy makers, researchers and the local people (Jones & Walsh, 2008). In this regards, we propose that local authorities, working with relevant institutions of higher learning, must champion evidence-based approaches, and these are enabled through stakeholder participation in policy formulation. We call for an inclusive participatory and holistic research involving a wider range of stakeholders to co-plan, co-design and co-manage adaptation and climate mitigation strategies.

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