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SCHOOL OF GEOGRAPHY, ARCHAEOLOGY AND ENVIRONMENTAL STUDIES

THE CLIMATE CHANGE–WATER–ENERGY NEXUS AND ITS IMPACTS ON URBAN LIVELIHOODS IN ZIMBABWE

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Declaration

I, Memory Reid, declare that this thesis, including the data, figures, tables, and any other information, is my original work. I have, where necessary, acknowledged the source(s) of the material that has been used.

This thesis contains my own writing. In areas that I have used another person's ideas, I have duly acknowledged the source(s). I have paraphrased ideas that have been borrowed from other authors and, in instances where their ideas have been used word-for-word, I have duly enclosed these ideas in quotation marks and referenced accordingly.

Furthermore, this thesis is being submitted for the award of the degree of Doctor of Philosophy to the Faculty of Science at the University of the Witwatersrand in Johannesburg, Republic of South Africa. This is the first time I am submitting this thesis for examination and the award of the degree thereafter. It has never been submitted to any other university before for a similar purpose.

Signed:
Memory Reid

Executive Summary

Climate change is predicted to greatly impact Southern African countries, largely due to variability in temperature and precipitation. These variations affect urban population livelihoods as well as water and energy security due to a heavy reliance on hydropower for energy. Using the Kariba sub-basin of the Zambezi River Basin, this study examines the possible impacts of hydroclimatic variations on future water and energy security in Zimbabwe. Over 50 years of hydroclimatic and hydropower output data was combined with data from surveys of informal businesses reliant on electricity to generate information on the vulnerability of urban livelihoods to energy insecurity in Zimbabwe. Interviews with key informants were used to understand the roles of various government institutions in climate change mitigation, water resource management, energy and the informal sector. Results of hydroclimatic patterns showed a general warming and drying trend for the Kariba sub-basin, variability in Zambezi River runoff and reduced hydropower output over time. Hydroclimatic variables impacted hydropower generation, confirming a climate change-water-energy nexus. Household survey data revealed home-based informal businesses across all socio-economic backgrounds, heavily reliant on an unstable electricity supply. Poor households were disproportionately affected by the unstable electricity supply because they could not afford alternative energy sources to continue business during power cuts. This highlighted the vulnerability of poor urban populations and their diminished capacity to adapt to climate change induced stresses. It was established that while national governmental bodies provided overall leadership on climate change issues, they also created an enabling environment for Small and Medium Enterprises through enacting laws and legislation. Climate trends and energy insecurity add to these complexities as marginalised groups fail to adapt to the impacts of energy insecurity on their livelihoods. This study highlighted the importance of exploring and cultivating a range of energy options to sufficiently mitigate against the impacts of climate change on access to energy and on urban livelihoods. Energy mixes that do not depend only on climate sensitive technology like hydropower should be considered. Furthermore, governments need to play a direct, gender-specific role in an informal sector dominated by women with limited bargaining power for the growth of their businesses.

Key words: climate change, water resources, hydropower, energy security, Zambezi River Basin, urban livelihoods, informal sector.

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List of Abbreviations and Acronyms

CAPCO	Central African Power Cooperation
CBD	Central Business District
CBZ	Central Bank of Zimbabwe
COVID-19	Coronavirus Disease of 2019
DSM	Demand Side Management
EU	European Union
GDP	Gross Domestic Product
GHG	Green House Gas
GW	Gigawatts
HBE	Home Based Enterprises
HDRAs	High Density Residential Areas
ICLS	International Conference of Labour Statisticians
IEA	International Energy Agency
IHA	International Hydropower Agency/Authority
ILO	International Labour Organisation
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Producer
IRENA	International Renewable Energy Agency
ISO	Informal Sector Operations
IWR	Institute of Water Resources
JOTC	Joint Operations Technical Committee
kWh	Kilowatt-hour
LDRAs	Low Density Residential Areas
LFS	Labour Force Survey
MAP	Mean Annual Precipitation
MASA	Meteorological Association of Southern Africa
MDRAs	Medium Density Residential Areas
MSD	Meteorological Service Department
MSME	Micro, Small and Medium Enterprises

NACOF	National Climate Outlook Forum
NASA	National Aeronautics and Space Administration
NCCRS	National Climate Change Response Strategy
NCP	National Climate Policy
NGO	Non-Governmental Organisation
NWRMP	National Water Resources Master Plan
PV	Photovoltaics
SARCOF	Southern Africa Regional Climate Outlook Forum
SADC	Southern Africa Development Community
SAP	Structural Adjustment Programme
SAPP	Southern Africa Power Pool
SECA	Supporting Enhanced Climate Action
SME	Small and Medium Enterprise
SMEDCO	Small, Medium Enterprises Development Corporation
TWh	Terawatt-hours
UIM	Urban Industrial and Mining
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
USD	United States Dollars
WCD	World Commission on Dams
WMO	World Meteorological Organisation
ZAMCOM	Zambezi Basin Watercourse Commission
ZCTU	Zimbabwe Congress of Trade Unions
ZDAWU	Zimbabwe Domestic and Allied Workers Union
ZENT	ZESA Enterprises
ZERA	Zimbabwe Energy Regulatory Authority
ZESA	Zimbabwe Electricity Supply Authority
ZETDC	Zimbabwe Electricity Transmission and Distribution Company
ZIMRA	Zimbabwe Revenue Authority

ZINWA	Zimbabwe National Water Authority
ZPC	Zimbabwe Power Company
ZRA	Zambezi River Authority
ZRB	Zambezi River Basin
ZVDF	Zambezi Valley Development Fund

CHAPTER ONE: FRAMES OF REFERENCE

1.1 Background of the Study

Increases in atmospheric greenhouse gas (GHG) concentrations have changed the earth's climate. The Intergovernmental Panel on Climate Change (IPCC) predicts a rise in sea levels, higher temperatures, heavy rainfall events and more intense and frequent storms for the coming decades (IPCC, 2007a, 2014a). Global surface air temperatures rose by ~0.89°C between 1901 and 2019 (World Meteorological Organisation [WMO], 2020), with Africa's temperature predictions estimated to increase faster than the global average this century (Christensen *et al.*, 2007; James and Washington, 2013; IPCC, 2014a). The continent has shown a warming rate of about 0.05°C per decade, with a change in seasonal temperatures (Hulme *et al.*, 2001). Various models suggest that Africa's weather patterns will become more variable, and that the frequency of extreme weather events will increase (IPCC, 2014b). Temperature and rainfall variations, however, are likely to have the most considerable impacts for Africa (IPCC, 2007a) as reduced precipitation and increased evaporation due to high temperatures negatively affect surface water availability and, in turn, water dependent sectors like energy (Hulme *et al.*, 2001; Arnell, 2004; IPCC, 2007a; Yamba *et al.*, 2011).

As African leaders battle to grow their countries' economies and improve the livelihoods of their citizens, the growing demand for energy is of great importance. The development of climate-resilient energy sources is necessary for the sustainability of African economies. Coal, mainly from South Africa, dominates the continent's power generation, with 22% from hydropower, 17% from oil and 14% from gas which comes mainly from Nigeria (International Energy Agency [IEA], 2014). To date, hydropower remains the largest renewable energy source, making up 17% of electricity on the continent and projected to increase to 23% by 2040 (IEA, 2020). In southern Africa, hydropower contributes to about 40% of regional capacity (Spalding-Fecher et al. 2017), with dependencies higher for some nations. Climate change impacts on temperature and precipitation potentially threaten hydropower generation as they determine the amount of water available for hydropower generation (Mukheibir, 2007). In addition to climatic factors, natural and anthropogenic factors like slope, rock and soil type, land use and land cover affect river runoff, impacting on the water available for hydropower generation (Hodgkins et al., 2003; Milliman *et al.*, 2008; Seyam and Othman, 2015). However, river basins respond directly to precipitation amongst other hydrological factors influencing river runoff (Seyam and Othman, 2015) and in turn the water available for hydropower generation.

Droughts in Africa have historically disrupted hydropower generation, sometimes reducing plants to half of their capacity, leading to power rationing as was the case during the droughts in Kenya, Zimbabwe, Ghana and Tanzania (Chenje and Johnson, 1996; Mukheibir 2007; Zambezi River Authority [ZRA], 2019). In Southern Africa, droughts and accompanying low water levels at Kariba Dam and concomitant loss of electricity for Zimbabwe and Zambia occurred recently in 2016 (ZRA, 2016). In 2019, low water levels in Lake Kariba again precipitated power outages that led to a decrease in industrial production in the two countries (National Aeronautics and Space Administration [NASA], 2019; ZRA, 2019). Climate variability impacts on water resources negatively affect hydropower generation, exposing Africa's vulnerability to climate change. Irregular power supply can, therefore, have considerable negative impacts on economic development and, in turn, livelihoods on the continent (Sharife, 2009).

1.2 Thematic Considerations

Climate change impacts are already being felt in Zimbabwe. Average annual surface temperatures have increased by 0.4°C since 1900 (Brazier, 2015). Zimbabwe's National Climate Change Response (NCCRS) pointed out that the 1990s were the hottest decade in Zimbabwe in the last century (Government of Zimbabwe, 2015). The last century recorded a 5% decrease in precipitation, with more dry days in the rainy season (Brazier, 2015). The frequency of droughts and floods is reported to have increased since 1900, with flood events immediately preceded by drought years (Brazier, 2015; Government of Zimbabwe, 2015). The NCCRS of Zimbabwe predicted a temperature increase greater than the global average and a decrease in annual precipitation of between 5% and 18% for Zimbabwe (Government of Zimbabwe, 2015). Predictions of an annual rainfall decrease in all of Zimbabwe's catchments, except Mazowe and Manyame, with greater impacts on runoff more than precipitation and increases in incidents of extreme weather events exacerbate the situation (Davies and Hirjri, 2014; Moyo and Nangombe, 2015).

For Zimbabwe, an increase in rainfall variability will have a considerable effect, not only on water resources, but also on energy security and, in turn, citizen livelihoods. Zimbabwe's electricity is mainly generated from hydropower at Kariba Hydropower Station on Kariba Dam and coal from Hwange Thermal Power Station (Brown *et al.*, 2012; Kaseke, 2013; Zimbabwe Power Company [ZPC], 2018). The country's electricity demand is just over 2000 megawatts (MW), with the installed capacity standing at about 2000MW (Afshar, 2018; ZPC, 2018). However, the country generates well below the installed capacity due to aged equipment that requires recurrent maintenance, fuel shortages and periodic low lake levels at Kariba. Hydropower from Kariba Power Station has an installed capacity of 1050MW, contributing about 50% of installed capacity of electricity in Zimbabwe, and is the most reliable as it is not subject to frequent breakdowns; hence it has the full 1050MW capacity available (ZPC, 2018). The share from thermal power stations is significantly lower than installed capacity, with Hwange Thermal Power Station generating between 400-500MW despite an installed capacity of 920MW (Afshar, 2018). The contribution from the rest of the thermal power stations in Harare, Munyati and Bulawayo is insignificant or non-existent most of the time (Brown *et al.*, 2012; Kaseke, 2013; Afshar, 2018). Therefore, Kariba Hydropower Station's contribution of electricity to the national grid is well above 50% when lake levels are favourable. However, recent droughts have reduced the Zambezi River's inflows into Lake Kariba, resulting in the reduced power generating capacity of Kariba Hydropower Station. According to the ZRA, water levels in 2016 and 2019 were close to the lowest level required for energy generation, resulting in power cuts which negatively affected the economy as businesses failed to operate at capacity (ZRA, 2016; 2019). Hence, energy insecurity in Zimbabwe is potentially threatened by climate change due to its high dependency on hydropower. This will be largely felt in cities as they are large consumers of energy (United Nations Environment Programme [UNEP], 2011).

Energy drives the success and growth of cities as it is consumed by large industries, the informal sector and households (Karekezi and Majoro, 2002). In Africa, the informal sector is a source of livelihood for many and is dominated by the poor (Karekezi and Majoro, 2002; Potts, 2008). Many informal businesses, for example fabric work, welding and carpentry, and trades requiring refrigeration, are energy dependent. Though most informal enterprises are characterised by low to medium energy intensity use (Karekezi and Majoro, 2002), they are an important group to consider because they employ millions of people across the continent. The informal sector plays an important role in socio-economic development. According to Zimbabwe's Medium-Term Plan (2011-2015), micro, small and medium enterprises (MSMEs) contributed 60 % of gross domestic product (GDP) (Ministry of Economic Planning and Investment Promotion, 2011). According to the International Monetary Fund (IMF), the informal sector in Zimbabwe is ranked as one of the largest globally, hence its role is significant in supporting urban livelihoods in the country (Medina and Schneider, 2018). It is a source of income for retrenched professionals, skilled artisans, graduates entering the job market and uneducated and unskilled persons looking to earn a living (Chirisa, 2009; Njaya, 2015). The sector provides a means of alleviating poverty in urban areas as most people that practice the trades are the urban poor (Chirisa, 2009).

Energy insecurity impacts the productivity of businesses, including those in the informal sector. The sector is dominated by the urban poor, whose ability to adapt is limited, making them more vulnerable to the effects of energy insecurity.

Variability of climatic factors like temperature and precipitation impact on hydrological processes like river runoff, affecting water available for hydropower generation. Continuous power cuts due to a climate change-water-energy nexus deter the success of urban livelihoods. This study was therefore interested in investigating the climate change-water-energy nexus and its impacts on urban livelihoods. It also investigated the role played by institutions and policy makers in this nexus including urban livelihoods security. The overall aim was to investigate the impact of climatic and hydrological variability in the Kariba sub-basin on energy security and urban livelihoods in Zimbabwe.

1.3 Research Questions

In view of the above observations, the following research questions guided the research:

i. What are the inter-annual climatic, hydrological and hydropower generation trends observed in the Kariba sub-basin?
ii. What relationships exist among the climatic, hydrological and hydropower generation trends in the Kariba sub-basin?
iii. What makes up the informal enterprises in the urban areas of Zimbabwe?
iv. How does energy insecurity affect the informal sector as a source of urban livelihood?
v. What roles do institutions play in the sectors of climate change, water, energy and urban livelihoods?

1.4 Research Aims and Objectives

The main aim of this study was to investigate the impact of climatic and hydrological variability in the Kariba sub-basin on energy security and urban livelihoods in Zimbabwe.

The following were the objectives of the study:

i. To analyse long term, inter-annual climatic, hydrological and hydropower generation trends in the Kariba sub-basin,
ii. To identify the impacts of climatic and hydrological variability on hydropower generation in the Kariba sub-basin,
iii. To characterise the informal enterprises in the urban areas of Zimbabwe,
iv. To identify the impacts of energy insecurity on urban livelihoods and the adaptation mechanisms adopted for resilience, and
v. To examine the role of institutions and policy makers in the management of climate change impacts, water resource management, energy and urban livelihoods.

1.5 Summative Perspective on Key Literature of the Study

This section is dedicated to a summary of existing literature on the climate change-water-energy nexus and its impacts on urban livelihoods. It engages with the existing literature on the topic and outlines some thematic gaps that may exist within the literature, which should then justify this study. The literature is explored in greater detail in Chapter Two.

Global temperatures are predicted to increase by between 1.8 and 4.0°C, with temperature increases predicted to be greater on land than over oceans (IPCC, 2007a; 2014a). The above scenarios are said to result in a higher rate of evaporation and subsequently lead to more precipitation (IPCC, 2007a). However, precipitation will not be evenly distributed as some locations will get more or less rain, snow, or both, which will also vary in the winter and summer seasons (IPCC, 2007a). Furthermore, climate change impacts on temperature and precipitation threaten water resources and reduce its availability (Hulme *et al.*, 2001; Arnell, 2004; IPCC, 2007a; Yamba *et al.*, 2011).

Climate change impacts on water resources are also thought to impact energy (IEA, 2010a). Busby (2007) points out that securing adequate water supply is a concerning issue in the energy sector, especially considering the predicted impacts of climate change on water resources. Studies show that climate change will impact the energy sector through global warming, increase in extreme weather events and changing regional weather patterns, which includes the hydrological cycle (IPCC, 2007a; Beilfuss, 2012). The above situation will affect both energy supply and energy demand, with some regions' entire energy production and transmission structures affected (IPCC, 2007a; IEA, 2010; Beilfuss, 2012).

Climate change becomes a major concern for the energy sector as all energy technologies usually require large quantities of water. Research by van Vliet *et al.* (2016) alludes that hydropower and thermoelectric power contribute to 98% of the world's electricity generation, requiring large sums of water. Hydropower plants are water dependent as they require water to turn the turbines that generate electricity (Hamududu and Killingtveit, 2012; 2016; van Vliet *et al.*, 2016). With the predicted impacts of climate change said to affect water availability, energy security from hydropower stations is threatened (Hamududu and Killingtveit, 2012; 2016). Within Southern Africa (except South Africa), more than 60% of the countries are dependent on hydropower generated by the Zambezi River Basin (ZRB) (Beilfuss, 2012). The ZRB is the largest river basin in Southern Africa with an installed capacity of 5000MW (Beilfuss, 2012). However, the ZRB also has one of the most variable climates among major river basins in the world and is predicted to be the worst hit by climate change, with the semi-arid regions predicted to experience increased water stresses (IPCC, 2007a; Beilfuss, 2012).

Water dependent power generating technologies like hydropower play a huge role in a water-energy nexus, negatively impacted by climate change. Studies by Spalding-Fecher *et al.* (2017) suggest hydropower output to decline by 10-20% in the ZRB under a drying climate, with Zambia and Mozambique experiencing greater reductions than Zimbabwe and Malawi. The threat to energy generation indicates climate change's impact on economic development of the region. Historically, the ZRB's hydropower output has drastically reduced as dam water levels fell below generating capacity, forcing demand side management (DSM) policies to be implemented by several countries in the region (Ruppel, 2015). Literature by the ZRA supports the view that climate change will impact water resources and hydropower generation of the basin. The same literature suggests the existence of a climate change-water-energy nexus for sub-Saharan Africa, which can potentially impact energy dependant livelihoods. Research into the impacts of this nexus on energy dependent livelihoods becomes of utmost importance.

Low and middle-income countries make up two thirds of the global urban population and are likely to be hardest hit by the impacts of climate change (United Nations [UN], 2006). The demand for energy keeps rising in less developed countries and investigations on how climate change could potentially impact the availability of energy in cities are limited. Much of the current literature on the vulnerability of the urban poor to the impacts of climate change has been limited to the direct impacts of extreme weather events on urban populations, vulnerabilities due to lack of resilient infrastructure or services for the poor in urban areas (Carmin *et al.*, 2012). Limited literature has zoomed in on climate change's impacts on sources of livelihoods for the urban poor like the informal sector. Energy drives the success and growth of urban cities, including the informal sector. When the energy required in this sector is secured, the livelihoods of the urban poor are improved. Brew-Hammond (2010) views it is a productive use of energy that generates income and growth for the sector.

In 1998, the International Labour Organisation (ILO) in Kenya internationally recognised the informal sector as a way of doing things characterised by ease of entry, reliance on indigenous resources, family ownership, small scale operations, labour intensive and adaptive technology, skills acquired outside the formal sector, unregulated and competitive markets (ILO, 1998). Research has identified the informal sector as a source of livelihood for the urban poor as it provides employment, a means of alleviating poverty and contributes to the GDP (Karekezi and Majoro, 2002; Chirisa, 2009; Chirisa, 2013; Benjamin and Mbaye, 2014). The informal sector is dominated by women and provides a means for them to earn an income given that domestic roles and cultural barriers are restrictive and limit their opportunities (Eapen, 2001; Chirisa, 2009; Benjamin and Mbaye, 2012; Fapohunda, 2012). In addition, Chen (2001) points out that most women in the informal sector are normally self-employed or unpaid home-based workers.

Literature suggests that the employment opportunities created by the informal sector allow the urban poor to sustain their livelihoods and contribute to economic growth, poverty reduction and empowerment of women. It also suggests the existence of a climate change-water-energy nexus for sub-Saharan Africa. Exploration of this nexus and its impacts on urban livelihoods like the informal sector is necessary. The role played by institutions in development and implementation of strategies that build resilience to the impacts of a climate change induced energy crisis for the urban poor is also important. A detailed discussion on the different perspectives of studies of a similar nature has been presented in Chapter Two.

1.6 Summary of Some Methodological Considerations

This section is dedicated to a discussion on the methodology that was employed by this study. The current discussion is a summary that pre-empts a broader discussion on the methodology that will follow in Chapter Three.

A mixed method approach was used in the study by collecting both qualitative and quantitative data. This approach was complimentary to both qualitative and quantitative information, thereby increasing the scope and range of research to address the research aims and objectives (Johnson and Onwuegbuzie, 2004; Creswell and Clark, 2010). To shed light on the impacts of the climate change-water-energy nexus on the informal sector, primary and secondary sources of information were used. A combination of qualitative and quantitative data was collected through a household survey, by use of open and close-ended questionnaires to get information from women in the informal sector. The target population for this study was women in home-based informal work that is dependent on electricity. Their activities ranged from food services (catering, baking, food processing, refrigeration, etc), tailoring and grinding (mealie-meal, peanut butter) to hairdressing, printing, and packaging. The survey was conducted in the residential suburbs of Warren Park, Kambuzuma, Kuwadzana, Tynwald, Parktown, Borrowdale, Malborough and Greendale in Harare Urban district. The areas were chosen after drawing assumptions about their population densities and income levels based on their geospatial locations.

Information from key informants from local authorities and institutions using in-depth semi-structured interviews added to the qualitative data collected. These specialised actors from key institutions and relevant stakeholders provided information and gave in-depth context to the aim of the research. It was purposefully decided to work with people specialised in areas and sectors related to climate change, water resource management, energy security and urban informal livelihoods. Through the interviews, secondary data on climatic variables for the Kariba sub-basin was obtained from the Meteorological Service Department (MSD). The Zimbabwe National Water Authority (ZINWA) additionally provided secondary data on the hydrological variables of the Kariba sub-basin. The Kariba sub-basin, which is one of 13 sub-basins on the ZRB and spans between Zimbabwe and Zambia, was one of the study sites. Interviews were also conducted with the ZRA, Zimbabwe Electricity Supply Authority (ZESA), the Ministry of Energy and Power Development, the then Ministry of Environment, Water and Climate and that of Industry and Commerce, which housed the Medium and Small Enterprises Department. The proportion of electricity generated from hydroelectricity sources as a percentage of the total electricity generated in Zimbabwe was sourced from the World Bank website on global energy distribution. It was used to represent, to a large extent, long term time series data on electricity generated from the Kariba complex on the Zimbabwean side.

Given that the study employed a mixed method approach, data was analysed quantitatively and qualitatively. Quantitative data that addressed the climate change-water-energy nexus was analysed using R Statistical Package software, MAKESENS10, and Excel. Quantitative and qualitative data from the household survey was analysed using IBM SPSS software. Qualitative data from in-depth interviews with stakeholders was transcribed, analysed and presented using content analysis. Descriptive statistics were used to analyse the data on the socio-economic demographics of the respondents. Correlations were used to analyse the relationships between variables. A comparative analysis was carried out among residential areas and contrasted against different variables to compare different outcomes of the collected data. These included socio-economic, demographic, energy dependent informal activities, electricity availability, adaptive strategies employed and impacts on livelihoods. A detailed account of the step-by-step methodological imperatives employed by this study has been presented in Chapter Three of this thesis.

1.7. Scope and Limitations of the Study

The study focused on the informal sector referred to by the ILO (2003) as all employment arrangements that do not provide individuals with legal or social protection through their work, thereby leaving them more exposed to economic risk than others, whether or not the economic units they work for or operate in are formal enterprises, informal enterprises or households. The study focused on women in the home-based informal sector, whose activities were energy dependent. The focus was on women as studies have shown that women dominate the informal sector as a source of employment. With the commoditised nature of urban areas that requires a source of income, women find themselves involved in the informal sector, which is easy entry, to earn an income to take care of their families or compliment their spouses' efforts. Most women in the informal sector in Harare are involved in petty commodity trade and vending in multiple locations. These activities do not require the use of energy and, hence, have been excluded from the study as they do not provide a link between the climate change-water-energy nexus and livelihoods of people in the informal sector. The focus was on women in home-based trades as these are usually unaccounted for in labour force surveys. Women practice various trades in the comfort of their homes as this allows them to earn an income and still take care of their gender-based cultural roles as they raise their families. Furthermore, the electricity needed for some of these trades is easily accessible in residential homes in urban areas like Harare.

The participants were from nine different residential suburbs of Harare, differentiated by their geospatial locations, population densities and income levels. The fact that the household survey sampled respondents whose trade was based in their residential homes made it difficult to locate respondents and heavily depended on the knowledge and willingness of participants to give information about other women in the sector, hence, the snowballing sampling method was applied. There were challenges in zonation and residential area population in the survey. It became difficult to get the actual populations of residential areas for the study as Harare is officially marked by districts which cut across mixed residential areas, mixing high and low-income respondents. These districts are further divided into wards, which again cut across residential areas. Residential area population was also difficult to ascertain as local censuses like the 2012 ZIMSTAT population census are ward-based and not per residential area. Many residential areas are a complex mix of multiple household incomes. Therefore, for the purposes of this study assumptions were made that High Density Residential Areas (HDRAs) and Medium Density Residential Areas (MDRAs) in the south and south west of Harare are where the low- and middle-income urban populations reside, and the Low Density Residential Areas (LDRAs) of the north and north east are where the high income urban populations reside. The differences in income levels and population densities allowed a comparative study to be carried out by comparing demographics, livelihood strategies and adaptive strategies employed by different urban populations in different residential areas. It also made it possible to explore the various support structures that these populations have, from infrastructure, institutional to the local community level.

1.8 Ethical Considerations

A series of ethical considerations were drawn up to guide the research. These adhere to the ethical codes of the University of the Witwatersrand. Ethics are defined as the norms of conduct that differentiate between acceptable and unacceptable behaviour and guide the procedures of carrying out research (David and Resnik, 2015). It was important for the study to proceed in a manner that respects the privacy and opinions of the participants to collect accurate information. It was also important to conduct research in an ethical manner to gain the trust and mutual respect of the participants, encouraging them to freely participate in the study. Prior to data collection, all ethical considerations and protocols were considered. Ethics clearance for research was sought from the university and an Ethics Clearance Certificate was issued for the study (See Appendix N). During fieldwork, consent was sought from participants and respondents in the survey (See Appendix A). Time was taken to fully and meaningfully explain what the research was about and how it will be disseminated (See Appendices B and C). Participants were alerted to their right to refuse to participate, the extent to which confidentiality will be maintained, the potential uses of the data and, in some cases, their right to re-negotiate consent. The confidentiality of the information collected was preserved as numbers were used instead of names to conceal the identities of the participants. The information collected was used solely for the academic purposes of this study.

1.9. Definition of Keys Concepts

Several key terms pertaining to the climate change-water-energy nexus and urban livelihoods were used in the study. These terms are defined below according to how they are used in the thesis.

a) **Climate change** is defined as "a change of climate which is attributed, directly or indirectly, to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" by the United Nations Framework Convention on Climate Change (UNFCCC), in its Article 1 (UN, 1992). NASA defines climate change as "a long-term change in the average weather patterns that have come to define Earth's local, regional and global climates" (NASA, 2020). In this study, climate change will be used to mean a long-term change in global or regional climate patterns.

b) **Climate variability** is defined as variations in the mean state and other statistics of the climate on all temporal and spatial scales, beyond individual weather events (WMO, 2019). The same definition of climate variability was adopted by the IPCC, which goes on to state that variability could be due to natural or anthropogenic forces (IPCC, 2018). In this review, climate variability is defined as all the variations in the climate that last longer than individual weather events.

c) **Water withdrawal**. Kumar and Pavithra (2019) defined water withdrawal as freshwater taken from ground or surface water sources, either for all time or incidentally, and transported to the location of use. It is also defined as the volume of water removed from a source (IEA, 2016). The same definition will be used in this study.

d) **Water consumption** is defined as the volume of water withdrawn that is not returned to the source (i.e. it is evaporated or transported to another location) and is no longer available for other uses (IEA, 2016). It is complete removal of water from a source for use by humans, and is not returned to the source (Physicalgeography.net, 2009). The study will use water consumption to mean the portion of withdrawn water permanently lost from its source.

e) **Water availability**. The basic amount of long-term water available from surface and ground water inflows and rainfall compared to the demand. It is a fundamental determinant of water security (Zambezi Basin Watercourse Commission [ZAMCOM], 2015). The study defines it as the quantity of water that can be used for human purposes without significant harm to ecosystems or other users.

f) **Hydropower** is defined as a form of energy that harnesses the power of water in motion (National Geographic, 2020). It is flowing water creating energy that can be captured and turned into electricity (Renewable Energy World, n.d.). Hydropower is defined in the study as electricity generated from water in motion.

g) **Energy security** is the uninterrupted availability of energy sources at an affordable price (IEA, 2016). It is an adequate, stable and predictable energy supply to a nation. Hence, governments have to draw measures that meet national demand and keep energy stable and affordable. They ensure energy security by developing infrastructure that enables generation, storage and supply to end users (IPCC, 2018). The study defines energy security as uninterrupted availability of electricity at an affordable price.

h) **Climate change impacts.** The effects of climate change on natural and human systems (IPCC, 2007b). The study adopts the same definition.

i) **Livelihood.** According to Chambers and Conway (1991), a livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stress and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base. The study defines livelihoods as the activities performed to earn a living. These activities include those in the informal sector.

j) **Vulnerability** is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity and its adaptive capacity (IPCC, 2007b). This is the definition adopted by the study.

k) **Adaptation** is the process through which societies increase their ability to cope with an uncertain future, which involves taking appropriate action and making adjustments and changes to reduce the negative impacts of climate change (UNFCCC, 2007a). This definition is adopted by the study.

l) **Resilience** is the ability of a system, including management systems, to adapt to the impacts of climate change without excessive harm. It is determined by the degree to which the social system can organise itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures (IPCC, 2007b). The study adopts the same definition.

1.10. Structure of the Thesis

This thesis comprises of six chapters. **Chapter One** introduces how the research was conceptualised as well as the frames of reference. **Chapter Two** presents the literature review. Different literary materials were brought forward, with the objective of engaging both historical and contemporary arguments on issues related to the research theme under investigation. Methodological processes are presented and discussed in **Chapter Three**. In this chapter, the step-by-step process followed in the collection and analysis of data is discussed. **Chapter**

Four presents the empirical evidence in the study. This includes establishing the existence of a climate change-water-energy nexus and characterising the informal sector in the urban areas of Zimbabwe. The chapter explores the energy challenges of urban populations and highlights the participation of women in the informal sector. It also exposes how the climate change-energy nexus has impacted the livelihoods of those employed in the informal sector, the adaptive strategies by different socio-economic groups and their resilience to shocks and support structures. Furthermore, it details the role of institutions in supporting urban population resilience to the impacts of climate change on their livelihoods. **Chapter Five** focuses on data analysis and discussion of the issues addressed in Chapter Four. Finally, the conclusions and recommendations of the study are presented in **Chapter Six**.

CHAPTER TWO: THEORETICAL CONSIDERATIONS AND LITERATURE REVIEW [1]

This chapter discusses the existing literature on the topical issues related to this study in a bid to identify the gaps that exist within climate change-energy-water nexus and urban livelihoods research, particularly in a developing country. A literature review is defined as "an evidence-based, in-depth analysis of a subject" (Winchester and Salji, 2016). It informs on current knowledge of a subject area by providing a balanced view. It critically engages with the literature by debating on conflicting views as well as existing knowledge of a particular topic, exposing gaps in research (Winchester and Salji, 2016). A literature review helps to identify the need for additional research in a subject area, placing the study within the context of existing literature and thus justifying the need for the study.

This chapter reviews literature on climate change and its impacts on water resources and hydropower in Southern Africa, with emphasis on the Zambezi River Basin (ZRB). In addition, literature on the impacts of the climate change-water-energy nexus on energy security and its implications on urban livelihoods in Zimbabwe is examined. The chapter starts by defining key concepts used in the study. It goes on to outline global climate change trends and predictions, and their implications on water resources and hydropower in Africa and the ZRB. The chapter explores Africa's energy sector and linkages to a climate change-water-energy nexus, paying attention to the Kariba Dam and hydropower output for Zimbabwe. The chapter also addresses basin management challenges and opportunities. The proceeding section ties in the impacts of a climate change-water-energy nexus on urban livelihoods by first characterising informal urban livelihoods. It examines the role of women in the informal sector, energy use in urban livelihoods and institutional influence on urban livelihoods. The following section identifies the knowledge gap on climate change and its impacts on

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This chapter is based on a paper prepared for publication in the conference proceedings of the 3rd Water Energy Nexus 2020.

hydropower generation and urban livelihoods in literature before conclusion of the chapter.

2.1 Introduction

The Intergovernmental Panel on Climate Change (IPCC) has highlighted the impacts of human-induced global warming on our planet. Increase in multi-decadal warming has been observed, with the last three decades being the warmest on record (IPCC, 2014b). These climatic changes are predicted to give rise to more frequent and extreme weather events and rising sea levels, among other issues (IPCC, 2007a; 2014a). This directly impacts water resources. Africa already experiences highly variable climatic stresses, with some regions being the most variable in the world on both seasonal and decadal scales (IPCC, 2007a). Climate change aggravates the situation.

Climate change poses a threat to most of sub-Saharan Africa's water resources. Arnell (2004) predicts a dramatic increase in the number of people facing water stress in the next 50 years. Water and energy coalesced are the world's most crucial resources. They are the key to development and economic growth, as expressed by Hamiche *et al.* (2016). There is a growing demand for energy in Africa as it is essential for the continued growth of African economies and improvement of livelihoods (Sharife, 2009). Literature suggests a global increase in energy demand (IEA, 2010b; Beilfuss, 2012; IEA, 2020). The Nile, Congo, and Zambezi rivers hold most of the generating capacity on the African continent (Owusu *et al.*, 2008), making the region highly dependent on hydropower for energy.

Given that differences in temperature and rainfall are projected to be the two biggest impacts of climate change in Africa (IPCC, 2007a), they have the potential to affect hydropower stations. Studies have suggested this to mainly be through surface water evaporation, reduced runoff due to drought, increased runoff due to flooding and siltation deposits (World Commission on Dams [WCD], 2000; Schulze *et al.*, 2005; Mukheibir, 2007; Blackshear *et al.*, 2011; Mukheibir, 2013). Furthermore, there is strong evidence that droughts have disrupted hydroelectric generation, sometimes reducing plants to half of their capacity, leading to power cuts, as was the case during the droughts in Kenya, Zimbabwe, Ghana and Tanzania (Mukheibir, 2007; Owusu *et al.*, 2008; ZRA, 2016; 2019).

The impacts of climate change on hydropower generation expose Africa's dependency on it, making Africa vulnerable to future weather irregularities as previous droughts have shown. This puts economic development of the region at risk as energy drives commerce, predominantly in cities where demand continues to grow (IEA, 2020). In addition, energy supports the success of urban sources of livelihood like the informal sector. These are predominantly practiced by the urban poor who are more vulnerable to energy insecurity as their adaptive capacity is low. Hence, the potential impacts of climate change on hydropower potential threaten energy security and urban livelihoods in Africa.

2.2 A Global Perspective on Climate Change and its Implications on Water and Energy Resources

2.2.1 Climate change and its links to water and energy

Research on climate change has shown its potential to alter the ability of Earth's physical and biological systems (land, atmosphere and oceans) to provide goods and services essential for sustainable economic development (IPCC, 2007a). Several studies have revealed an increase in global surface temperatures in the 20th and 21st centuries. These increases are illustrated in Figure 2.1 from the IPCC Technical report of 2014. A warming of about 0.89°C in the global surface air temperatures was estimated between 1901 and 2012 (WMO, 2020). Furthermore, an increase of approximately 1°C above pre-industrial levels was reached globally in 2017 (Allen and Al, 2018). The decade 2010-2019 has been the hottest decade on record, with 2016 being the warmest year on record, followed by 2019 as reported by the WMO (2020). Currently, anthropogenic global warming is increasing at 0.2°C (IPCC, 2018). This indicates considerable increases in global temperatures, which potentially have devastating effects on the planet and its inhabitants.

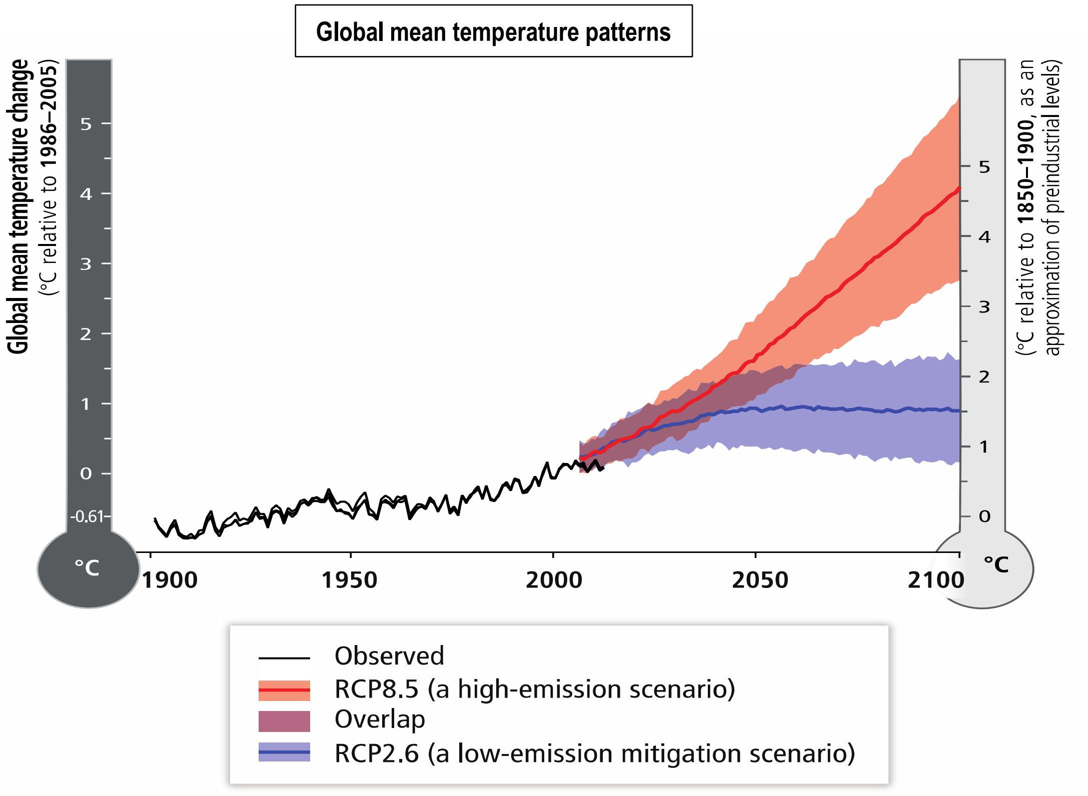

Figure 2.1 Past and projected global annual average surface temperature
Source: IPCC (2014a, p.14)

Studies by the IPCC suggest continued warming of the planet. Temperatures are predicted to increase by between 1.8 and 4.0°C, with temperature increases predicted to be greater on land than over oceans (IPCC, 2007a; 2014b; 2018). Between 2030 and 2050, these temperatures are projected to likely exceed 1.5°C if global warming continues at the current rate (IPCC, 2014b; 2018). Temperatures are also expected to be higher over high latitudes than tropics and mid latitudes. The above scenarios are said to result in a higher rate of evaporation and subsequently lead to more precipitation (IPCC, 2007a; 2018). However, precipitation will not be evenly distributed as some locations will get more rain, snow or both, while others will get less, which will also vary in the winter and summer seasons (IPCC, 2007a; 2014b; 2018). Collectively, the outlook suggests a warmer future with variations in precipitation.

Water resource use and function are threatened by climate change. A growing body of literature has shown that many regions are likely to experience reduced precipitation, increased surface water evaporation, and decreased river flows, runoff and ground water levels (Hulme *et al.*, 2001; Arnell, 2004; IPCC, 2007; Cisneros *et al.*, 2007; Kundzewicz *et al.*, 2007; Engelbrecht *et al.*, 2011; Yamba *et al.*, 2011; Arnell *et al.*, 2016). There is a consensus among researchers that water resources are arguably the most important domain to be considered because climate change has direct impacts on the availability, timing and variability of water supply and demand (Hulme *et al.*, 2001; Arnell, 2004; Yamba *et al.*, 2011). Literature suggests that water availability is among the most important resources, especially in a climate change scenario, as it is linked to many sectors including production in agriculture, food security, human health and well-being and energy generation (Fischer *et al.*, 2007; Parry, 2007; Tubiello and Fischer, 2007; Frumkin *et al.*, 2008; Brown, Hintermann and Higgins, 2009; Siddiqi and Anadon, 2011; Arnell *et al.*, 2016).

Economic and population growth, together with climate change, will increase demand for water and energy in the years ahead (IEA, 2015). Various literature points out how water and energy are interlinked, primarily in terms of resource use. Securing, delivering, treating and distributing water requires energy (Mielke *et al.,* 2010; Siddiqi and Anadon, 2011; Hamiche *et al,* 2016) . At the same time, water is used in all phases of energy production and electricity generation, from developing to processing and delivery for consumption (King *et al.*, 2008; Rio Carrillo and Frei, 2009). It has also been pointed out by the IEA (2016) that 10% of global water withdrawals and consumptions come from the energy sector. Edifying this observation, the IEA (2016) projects that between 2014 and 2040, water consumption from the energy sector will increase by close to 60%. Currently, the water sectors in the United States of America (USA) and European Union (EU) consume about 3% of electricity (IEA, 2016). The Middle East's water sector is set to increase electricity use from 9% in 2015 to 16% by 2040 (IEA, 2016). Furthermore, desalination is set to double the amount of energy used in the water sector over the next 30 years (IEA, 2016). It is therefore evident that water consumes electricity and vice-versa. In addition, the growing demand for water and energy will result in increased dependencies on the resources.

There is agreement in literature that most energy technologies require large quantities of water (IPCC, 2007; Rio Carrillo and Frei, 2009; Siddiqi and Anadon, 2011; IEA, 2016; van Vliet *et al.*, 2016a). Fossil fuel and nuclear reactor electric generation plants use water for functions including cooling, steam generation and waste disposal (Rio Carrillo and Frei, 2009; Siddiqi and Anadon, 2011). One limitation of implementing carbon capture and storage technologies to mitigate emissions by coal plants has been the amount of water required. It has been argued that these modifications would more than double their water consumption (IPCC, 2007; King *et al.*, 2008). Hydropower plants are also water dependent as they require water to turn turbines to generate electricity (Hamududu and Killingtveit, 2012; 2016; van Vliet *et al.*, 2016a). Research shows hydropower and thermoelectric power contributing to 98% of the world's electricity generation, requiring large sums of water (Van Vliet *et al.*, 2016a). There is limited literature on water use by other energy sources besides thermal and hydropower. Tan and Zhi (2016) compared water use for different energy sources and found biofuel production to be the most water intense with massive water consumption. On the other hand, solar and wind required the least amount of water. Notably, the technologies that use less water are the least developed globally, although there is growing demand in some regions as these sources are renewable forms of energy. There is agreement that an interdependence between water and energy is present, with advancements in technology continuing to strengthen the relationship. A water-energy nexus exists and has a strong bearing on energy security.

Current literature on energy points to hydropower as the largest renewable electricity technology. Global installed hydropower stood at about 1307GW in

2019, with major projects from China, Brazil and India projected to contribute a 9% increase by 2024 (IEA, 2020; International Hydropower Association [IHA], 2020). The dominance of these countries in hydropower expansion is likely due to economic growth and increased energy demand. The year 2019 saw a 45% reduction in net additions as China slowed down construction (IEA, 2020). Global capacity expansion in hydropower is expected to continue to decrease as large projects in China and Brazil face environmental restrictions, together with challenges from the Coronavirus Disease of 2019 (COVID-19) global pandemic (IEA, 2020).

Studies show that climate change impacts the energy sector through global warming, increase in extreme weather events and changing regional weather patterns, which includes the hydrological cycle (Beilfuss, 2012; IPCC, 2014a). The above situation is said to affect both energy supply and energy demand, with some regions entire energy production and transmission structures affected (IPCC, 2007a; IEA, 2010b; Beilfuss, 2012).This is evident as global usage of hydropower and thermoelectric power has historically been impacted by warm and drought years (van Vliet, 2016). Together, these studies highlight the potential influence that climate change has on the interdependence of water and energy, endangering water and energy security.

Several studies have presented variables that are thought to impact hydropower generation due to climate change. Cisneros *et al.* (2014) points out that mean annual streamflow, shifts in seasonal flows, and increases in streamflow variabilities are the main hydrological variables that are impacted by climate change and influence hydropower generation. Additions to those variables include increase in evaporation from reservoirs and changes in sediment fluxes. Mukheibir (2007) listed surface water evaporation, reduced runoff due to drought, increased runoff due to flooding and siltation deposits as the four major ways that temperature and rainfall potentially impact hydropower generation. The WCD recognised five different ways that climate change can affect hydropower installations. These are reduced reservoir inflows, increased surface water evaporation, increased extreme flooding (inflow), altered timing of wet season flows and increased sediment load in reservoirs (WCD, 2000). The IEA (2012) points out that climate change can impact hydropower generation by changes in river flow, increases in extreme weather events like floods and droughts and changes in sedimentation. Collectively, these studies outline the critical role that climate change plays in water availability for hydropower generation. Ultimately, the amount of water available to turn the turbines for power generation is the most important. Hence, how climate change impacts hydropower generation is assessed by determining the water available for hydropower generation.

It has been argued that how a hydropower plant is impacted by climate change also depends on the type of hydropower plant. However, the type of hydropower plant does not diminish the effect climate change has on hydropower generation. Hydropower schemes are classified by type: pumped storage, reservoir and run-of-river. Run-of-river power plants experience more flow variability than plants at reservoirs, hence, they are more susceptible to the impacts of climate change (Golombek *et al.*, 2012). Blackshear *et al.* (2011) created a framework to illustrate how climate change will affect hydropower as precipitation and temperature changes impact evaporation, discharge, temporal variability (flooding and droughts) and glacial melt. This was drawn against type of hydropower station to determine the impacts of climate change on hydropower facilities with differing structural characteristics to develop a typology of dams.

Literature has acknowledged that evaporation of water from the surface of reservoirs, especially upstream reservoirs and floodplains, accounts for the greatest loss of potential water, reducing generating capacity of hydropower plants (WCD, 2000; Mukheibir, 2007). In addition to this, studies highlight that the climate of the region determines the rate of evaporation from a water source, with higher temperatures resulting in higher water losses. They also claim that deeper dams with smaller surface areas tend to lose less water to evaporation than shallow, large-surface ones (McJannet *et al.*, 2008; Gleick, 1994). As global temperatures are predicted to increase, it would follow that water losses from large reservoirs in warmer areas are likely to increase, impacting hydropower generation. The ZRB is one such area as temperatures are high and several large reservoirs are populated there. Another factor considered by Mukheibir (2007) to affect evaporation rate is humidity. He compared Congo and Zambezi basin humidity, suggesting lower evaporation rates for the Congo Basin than the Zambezi Basin as the former is more humid than the latter. Hence, water losses in the semi-arid ZRB are likely to increase as predicted increases in temperatures will increase evaporation rates in the basin. This has a bearing on water resource use in the region, which subsequently impacts hydropower generation.

Schulze *et al.* (2005) pointed out that climate variability significantly impacts water resources, particularly river runoff. Periods of high temperatures and reduced precipitation result in droughts and subsequent reduction in runoff and vice-versa, as supported by Mukheibir (2013). Therefore, the reduction in reservoir inflows will have an impact on the energy generating capacity of hydropower plants. Mukheibir (2013) goes on to say strong floods may also damage dam structures and sediment deposits may block power generating equipment. The lifespan and reservoir capacity of dams can be reduced when reservoirs fill up with sediment deposits from flooding events. Watts *et al.* (2011) emphasises that flooding in dams due to climate change also requires management of floodplains and wetland ecosystems on top of the obvious engineering techniques, due to the multifunctional nature of dams; hence, broader considerations are necessary.

Since climate change is said to impact temperature and precipitation, it increases the likelihood of extreme events such as droughts and floods occurring. These potentially influence the lifespan of reservoirs, affecting their capacity to generate electricity. If runoff is affected, this directly impacts hydropower generation, a view supported by Mukheibir (2013). Tang *et al.* (2013) also establish a relationship between climatic factors and runoff in the Yellow River in Asia, with a decrease in precipitation resulting in a decrease in runoff. The consensus is that the amount of water in the reservoir matters most. Hence, the direct impact of climate change on the water available to generate electricity is the ultimate determinant of hydropower success.

2.3 Climate Change and its Implications on Water Resources and Energy Security in Africa

2.3.1 Climate change predictions and water resources

Studies suggest Africa to be susceptible to the impacts of climate change due to its low adaptive capacity, with Southern Africa being one of the most vulnerable regions in Africa (Callaway, 2004; IPCC, 2007a; 2014a; Ziervogel *et al.*, 2014). Niang *et al.* (2015) have seen an increase in near surface temperatures over the last 50 years in West Africa and the Sahel. Others have found Southern Africa to be showing a warming and drying trend (New *et al.*, 2000; Hulme *et al.*, 2001; Tadross *et al.*, 2005; New *et al.*, 2006; Christensen *et al.*, 2007; Engelbrecht *et al.*, 2009; Engelbrecht *et al.*, 2011; Engelbrecht *et al.*, 2013). New *et al.* (2006) highlighted that inland Southern Africa experienced a more rapid increase in minimum temperatures relative to maximum temperatures. Moreover, New *et al.* (2006) also found an increase in the number of dry days in the region, with increase in temperature extremes in the last decades of the 20th century. Hulme *et al.* (2001) showed a warming rate of 0.5°C per century between 1900 and 2000, with 1998 being the warmest year for Africa and the interior of Southern Africa warming at 2°C per century. Southern Africa's mean annual temperature was an alarming 1°C above the average of the years 1981-2010 (WMO, 2020). Collectively, research in the climatic observations for Africa shows a general warming and drying trend. These and other observations are represented in Table 2.1 below of the IPCC 2014 Technical Summary.

Table 2.1 Climate change impacts in Africa

Africa	
Snow & Ice, Rivers & Lakes, Floods & Drought	• Retreat of tropical highland glaciers in East Africa (*high confidence*, major contribution from climate change) • Reduced discharge in West African rivers (*low confidence*, major contribution from climate change) • Lake surface warming and water column stratification increases in the Great Lakes and Lake Kariba (*high confidence*, major contribution from climate change) • Increased soil moisture drought in the Sahel since 1970, partially wetter conditions since 1990 (*medium confidence*, major contribution from climate change) [22.2, 22.3, Tables 18-5, 18-6, and 22-3]
Terrestrial Ecosystems	• Tree density decreases in western Sahel and semi-arid Morocco, beyond changes due to land use (*medium confidence*, major contribution from climate change) • Range shifts of several southern plants and animals, beyond changes due to land use (*medium confidence*, major contribution from climate change) • Increases in wildfires on Mt. Kilimanjaro (*low confidence*, major contribution from climate change) [22.3, Tables 18-7 and 22-3]
Coastal Erosion & Marine Ecosystems	• Decline in coral reefs in tropical African waters, beyond decline due to human impacts (*high confidence*, major contribution from climate change) [Table 18-8]
Food Production & Livelihoods	• Adaptive responses to changing rainfall by South African farmers, beyond changes due to economic conditions (*very low confidence*, major contribution from climate change) • Decline in fruit-bearing trees in Sahel (*low confidence*, major contribution from climate change) • Malaria increases in Kenyan highlands, beyond changes due to vaccination, drug resistance, demography, and livelihoods (*low confidence*, minor contribution from climate change) • Reduced fisheries productivity of Great Lakes and Lake Kariba, beyond changes due to fisheries management and land use (*low confidence*, minor contribution from climate change) [7.2, 11.5, 13.2, 22.3, Table 18-9]

Source: IPCC (2014a, p.30)

Literature on Africa's temperature predictions estimates an increase faster than the global average in the 21st century (Christensen *et al.*, 2007; James and Washington, 2013). Africa's projected temperature is expected to exceed observed temperatures between 1986 and 2005 by 3°C to 6°C (IPCC, 2014a). Hulme *et al.* (2001) predict an increase of between 2°C and 6°C in the next century for Africa. Countries in the tropics, especially tropical West Africa are expected to reach predicted global average temperatures one to two decades earlier than the global average (Niang *et al.*, 2014). Warmer conditions are predicted for Southern Africa, with an annual increase of +3.4°C and general warming in all seasons (+3.1°C DJF, MAM to +3.7°C SON)(Christensen *et al.*, 2007; James and Washington, 2013). Overall, evidence seems to indicate a warming trend on the continent, with predictions suggesting a continued warming trend above the global average. This has negative implications on water resource use, especially for Southern Africa which already experiences water stresses.

The Sahel regions in North Africa have experienced a reduction in precipitation in the 20th century, while high variability has been recorded in East Africa. The western region of Southern Africa has experienced downward trends in summer rains (Niang *et al.*, 2014). High inter-annual variability was observed for Africa, with decrease in summer rains (DJF), including South Africa and Namibia with reductions of 15%-25% (Hulme *et al.*, 2001). Projections show a likely drying trend for North Africa and a wet trend for East Africa by the end of the 21st century (Niang *et al.*, 2014). Drier conditions are predicted for Southern Africa with an annual decrease of 4% in precipitation (Christensen *et al.*, 2007). Precipitation will decrease by 23% in JJA and 13% in SON, with no changes for DJF and MAM (Christensen *et al.*, 2007). Shongwe *et al.* (2009) predict severe droughts in the southwest of Southern Africa and increased rainfall north of the region in Zambia, Malawi and northern Mozambique. In addition, Shongwe *et al.* (2009) predict a delay and shorter session of the rainy season in many parts of Southern Africa. Literature collectively speaks to a reduction in precipitation for most regions in Africa, except East Africa. Water availability under such conditions is threatened for the rest of Africa.

Several studies have noted changes in summer patterns, influenced by changes in precipitation and increase in temperatures. Drying over Southern Africa, with drier summers, the strongest projections being for Zimbabwe and Botswana, was observed by Engelbrecht *et al.* (2011). This may increase water scarcity, extend desert areas further eastwards, reduce agricultural productivity, and increase food insecurity and famine. Mason (2001) observed increases in flooding events over Southern Africa, while increases in extreme rainfall events driven by intensive convective rainfall events were predicted (Mason and Joubert, 1997; Engelbrecht, Engelbrecht and Dyson, 2013). A broader perspective has been adopted by Kundzewicz *et al.* (2013) who project that the impacts of floods and droughts will increase, even when the hazard remains constant, owing to increased exposure and vulnerability. In recent times, tropical cyclone Idai hit the eastern coast of Africa, with devastating effects in Mozambique, Malawi and Zimbabwe (WMO, 2020). It brought storm surges, strong winds, landfalls and flooding, displacing and disconnecting communities, and destroying infrastructure, including hydropower plants. The events that followed Cyclone Idai, together with the studies above, are representative of the devastating impacts that extreme weather events will have on the continent. These events heavily impact Africa, which already has limited adaptive capacity and preparedness.

It has been argued that Africa's water resources exhibit high temporal and spatial variability, suggesting water scarcity to be a major concern for the continent. Arnell (2004) highlights that increases in population, economic activity and energy demand will impact Africa's water use. The author estimates 75-250 million people in Africa to be at risk of increased water stress by 2020, with a further 350-600 million by the 2050s. However, literature fails to consider ground water and how it will impact water availability, as many studies are centred around surface water sources. Kundzewicz *et al.* (2007) suggest a potential increase in ground water demand as water use increases, a situation also favoured in response to changes in surface water availability. Behavioural changes are thought to impact water demand as higher temperatures will modify water consumption patterns. Goulden *et al.* (2009), for example, point out that in Africa, where a lot of economies are agrarian based, climate change impacts on water availability may influence decisions to expand irrigation schemes to counter unavailability of seasonal rains or surface water availability. Overall, literature points to population growth and increase in energy demand and water consumption to represent the challenges of managing water resources on the continent. These are worsened by the impacts of climate change.

2.3.2 Regional energy structures

Sub-Saharan Africa's energy supply and access is poor, although it is rich in energy resources (IEA, 2014; 2015). Brew-Hammond (2010) puts sub-Saharan Africa's access to electricity around 25%, but it grew to about 45% in 2018, according to the IHA (2020) and the IEA (2020). With a continuously growing population that accounts for 17% of the world's population, it only takes up 4% of the world's energy demand (IEA, 2019; IHA, 2020). Despite its low energy demand globally, rapid economic growth in sub-Saharan Africa since 2000 has seen an increase in energy use by 45% (IEA, 2014). The IHA (2020) points out that energy demand on the continent is growing faster than the global average. However, Africa's population without access to electricity's growth rate is higher than its energy demand. Figure 2.2 illustrates how Africa accounts for a low share of the world's energy demand and high share of the global population without access to modern energy services. On a continent where supply does not meet demand, demand is growing and access is limited, with climate change's potential impact on energy generation adding to the complexities of energy security on the continent.

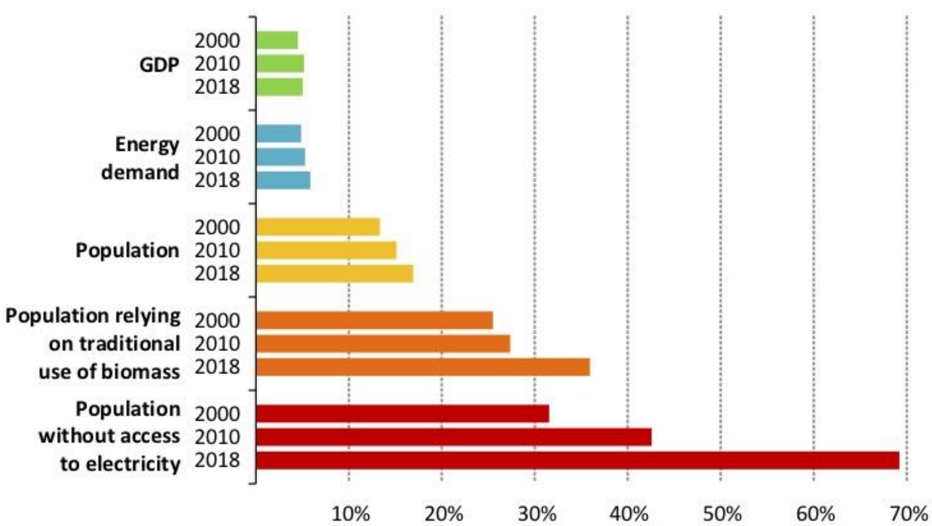

Figure 2.2 Africa's share of global indicators
Source: IEA (2019, p.20)

There are varying statistics on Africa's installed and potential capacity as it changes over time. In 2012, the on-grid power generation capacity was 90 gigawatts (GW), with South Africa generating about half of it, mainly from thermal coal power stations. The International Renewable Energy Agency (IRENA) estimates Africa's installed capacity and annual energy consumption to be 125 GW and 600 terawatt-hours (TWh) respectively (Ndhlukula *et al.*, 2015). Excluding South Africa, the rest of the continent is heavily dependent on hydropower generated mainly from the Nile, Congo and Zambezi river basins (Owusu *et al.*, 2008; Beilfuss, 2012; World Energy Council, 2013). These dependencies are mapped out in Figure 2.3

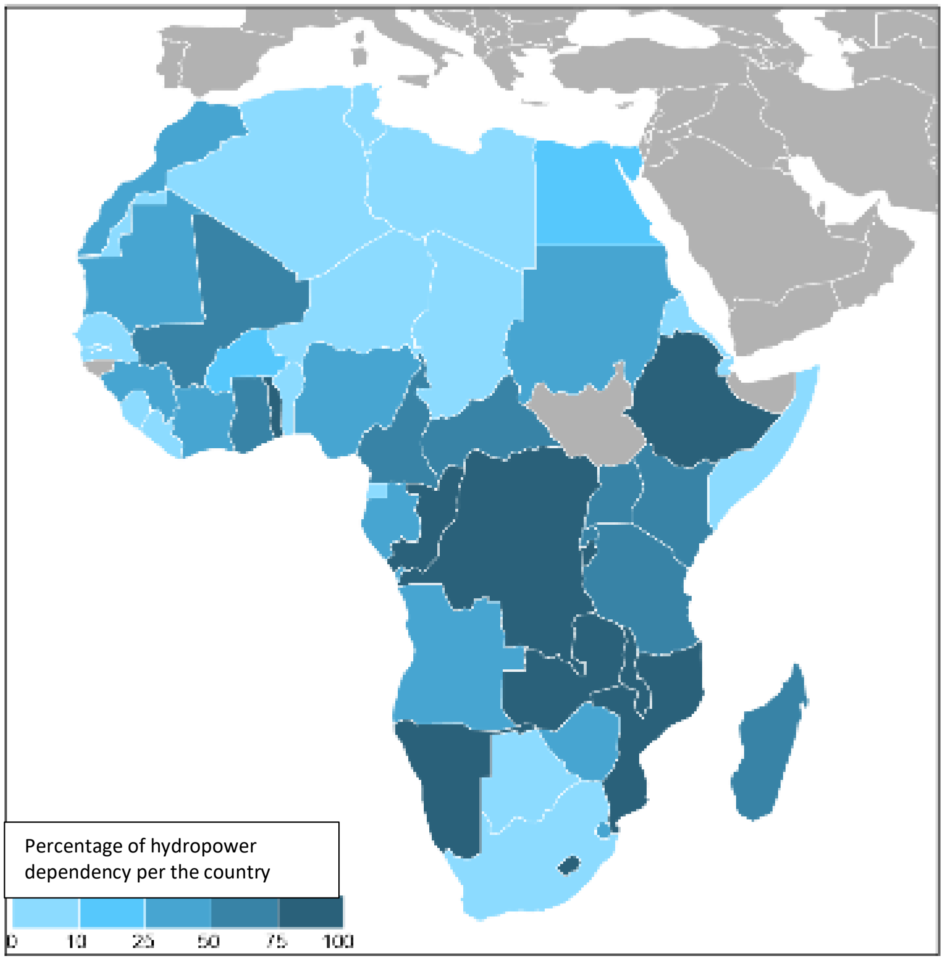

Figure 2.3 African hydropower dependence as a percentage of capacity
Source: US Energy Administration 2008 crossref (Blackshear *et al.*, 2011)

Hydropower plays an important role in many countries' decarbonisation plans. However, it is vulnerable to climate variability**.** According to the IEA (2020), on average, 17% of electricity generated on the African continent is from hydropower. It is set to increase to about 23% by 2040. The installed capacity of hydropower in Africa stood at over 37GW in 2019 and remains the main source of renewable energy on the continent (IHA, 2020). Hydropower capacities are illustrated in Table 2.2. Hydropower expansion projects have increased the continent's capacity and resulted in an annual growth rate of 4.4% in the past decade, according to the IHA (2020). However, obsolete and aged hydropower plants result in not generating at capacity. According to the IHA, hydropower power plants aged 20 years or older make up 60% of the plants in Africa. Their age, together with the effects of climate change, have affected average annual growth, dropping it to 2.4% per year (IHA, 2020). This situation takes away from the potential economic growth of the continent, with climate change exacerbating the situation.

Table 2.2 Africa’s installed hydropower capacity per country as of 2019

Hydropower capacities in Africa

Rank	Country	Total installed capacity (MW)
1	Ethiopia	4,074
2	South Africa	3,596
3	Angola	3,435
4	Egypt	2,876
5	Democratic Republic of the Congo	2,750
6	Zambia	2,400
7	Mozambique	2,216
8	Nigeria	2,110
9	Sudan	1,923
10	Morocco	1,770
11	Ghana	1,584
12	Zimbabwe	1,076
13	Uganda	1,040
14	Cote D'Ivoire	879
15	Kenya	826
16	Cameroon	792
17	Tanzania	586
18	Malawi	371
19	Guinea	368
20	Namibia	347
21	Gabon	331
22	Algeria	269
23	Congo	218
24	Mali	180
25	Madagascar	164
26	Reunion	134
27	Equatorial Guinea	128
28	Rwanda	111
29	Liberia	93
30	Senegal	81
31	Lesotho	73
32	Tunisia	66
33	Sierra Leone	64
34	Mauritius	60
35	Eswatini	60
36	Burundi	58
37	Togo	49
38	Mauritania	48
39	Burkina Faso	34
40	Benin	33
41	Central African Republic	19
42	Sao Tome And Principe	2
43	Comoros	1

Including pumped storage

Source: IHA (2020, p.34)

Within Southern Africa (except South Africa) more than 60% of the countries are dependent on hydropower mainly generated in the ZRB, with dependency even higher for some nations (IEA, 2010; Beilfuss, 2012). Spalding-Fecher *et al.* (2017) state that hydropower contributes to about 40% of the regional power capacity with over 40 000MW in generation potential. Electricity demand is unevenly distributed, with South Africa carrying the highest demand to power its major cities and industries, especially mining. The region has an integrated network where electricity is traded through the Southern African Power Pool (SAPP). It was developed by 12 energy generating bodies from Southern Africa Development Community (SADC) countries in 1995, connected through a grid to alleviate shortfalls in electricity capacities. It was established to develop an interconnected electrical system, coordinate and enforce common regional standards, harmonise relationships, develop expertise across member utilities, and promote sustainable development (SAPP, 2015). Zimbabwe's power utility, ZESA, is part of this network. Although Southern Africa has an established interconnected electricity network through the SAPP, its high dependence on hydropower potentially threatens energy security in the region as hydropower is sensitive to climate variability, as has been historically experienced.

Future investments in energy include expansion of coal fired thermal stations in South Africa, with investments in hydropower to include extensions of already existing stations and building of new dams along the basin (Beilfuss, 2012). One example is the proposed Grand Inga in the Democratic Republic of the Congo along the Congo Basin, with an estimated capacity of 39GW using 52 turbines. According to International Rivers (2016), electricity from this project could result in tremendous benefits to African industries, although huge environmental and social concerns come with the construction of this dam. As a result, work on this project has halted and investors like the World Bank have pulled out. Although hydropower is characterised by high capital costs, it has relatively low operational costs that fall anywhere between 0.037-0.047USD/kilowatt-hour (kWh) for capacities greater than 1MW, compared to fossil fuels that are between 0.050 to 0.177USD/kWh (IRENA, 2020). This has made it a favourable option in many countries' energy expansion projects. However, the return on investment takes longer when compared to other energy technologies (Mukheibir, 2013; REN21, 2020). The region is already dependant on an energy technology that requires large water withdrawal and consumption, including future expansion projects. Given the historic patterns that climate change and variability impact water resources, the continent and Southern Africa's energy security is imperilled. Investments in other energy technologies like gas, solar and wind are in the pipeline, however, there seems to be no equitable development in those sources of energy.

2.3.3 Hydropower and climate change

Global hydropower capacity has been increasing steadily, with more hydropower plants proposed for Africa as demand for electricity grows. It is seen as a clean, reliable and affordable source of energy by donors and investors, hence, investments in hydropower continue to grow (Cole *et al.,* 2014). Conway *et al.* (2015) state that the largest number of dams in the region are in South Africa and Zimbabwe but are used predominantly for irrigation and water supply than for electricity generation, with dams in Mozambique carrying some of the largest capacities. Mukheibir (2013) argues that large reservoirs are more easily able to absorb fluctuations in river flow over a longer period than run-of-river plants and represent the majority of dams in Africa. However, water losses from large reservoirs are also huge (WCD, 2000) and likely to worsen with the continued warming trend predicted for the continent, reducing water availability and subsequently impacting hydropower generation.

Hydropower has been a favoured energy source because it is reliable and not subject to international price fluctuations compared to other sources like fossil fuels (IRENA, 2020). Southern Africa has a huge energy potential but lacks the capacity to develop it (Ruppel, 2015). The IPCC (2011) and Cole *et al.* (2014) point out that hydropower can meet peak demand as it is stored energy from the existing potential from dam water. Dams can also be used as storage for water which can be used for irrigation, transport and recreation, among many other uses, and is also a renewable source of energy (IPCC, 2011; Cole *et al.*, 2014). However, hydropower's dependence on water poses a concern in a changing climate scenario where storage results in high evaporative losses.

While the overall impacts of climate change on global hydropower potential appear to be slightly positive or impact minimally, according to the IPCC (2011) and Hamududu and Killingtveit (2012), the high climate variability of Southern Africa poses a concern for hydropower potential in the region. Existing research recognises the predicted impacts of climate change on water resources, suggesting the existence of a climate change and energy nexus (Gleick, 1989; 1994; Arnell, 1999; 2004; Yamba *et al.*, 2011). Water resource availability dictates water supply and energy security, with water dependent power generating technologies like hydropower playing a huge role in this nexus. Their ability to generate electricity is heavily dependent on water availability. With the predicted impacts of climate change said to affect water availability, Hamududu and Killingtveit (2012; 2016) add to the conclusion that energy security from hydropower stations is threatened.

2.4 Climate Change in Zambezi River Basin and its Implications on Hydropower for Zimbabwe

2.4.1 Climatic patterns on the Zambezi

The ZRB has one of the most variable climates among major river basins in the world (Tumbare, 2010; ZAMCOM, 2015). The IPCC (2001) found the ZRB to be impacted the most by climate change when compared to other river basins in Africa. Climate modelling for the ZRB suggests a significant warming trend in the next century, with an increase of 0.3-0.6°C per decade (Christensen *et al.*, 2007; Beilfuss, 2012). The highly arid south/southwestern areas of the ZRB are projected to have substantial temperature increases (Christensen *et al.*, 2007). Hamududu and Killingtveit (2016) indicate an increase of up to 2.7°C by the end of the century in the Zambezi Basin. Higher rates of evaporation and transpiration are expected because of increases in temperature in the region. Beilfuss (2012) elaborates by stating that evaporation exceeds rainfall during every month of the calendar year in each of the 13 sub-basins, with a mean annual potential evapotranspiration of 1,560mm across the basin. This suggests that water losses are high and water scarcity is potentially increasing over time as a continued warming trend is predicted in the ZRB.

The ZRB exhibits high rainfall variability across the basin from high regions in the north and arid/semiarid regions in the south and southwest with high inter annual variability in rainfall (Tumbare, 2010; ZAMCOM, 2015). Studies show a rainfall decrease of 10-15%, delayed onsets, together with shorter and more intense rainfall events (IPCC, 2007a). Shongwe *et al.* (2009) noted a shortened rainy season in the basin, especially in the northern parts. Other studies have highlighted increased weather extremes, increased extremely wet austral summers and extremely dry austral winters and springs (Tadross *et al.*, 2005; New *et al.*, 2006; IPCC, 2007a). The analysis of the ZRB's historic extreme weather events for over 200 years of rainfall by Tumbare (2010) indicated that 30% of the years under study were drought years. This compelling study accentuates the ZRB's aridity and how it is prone to extremely dry periods. Rainfall patterns seem to suggest a decrease in precipitation and an increase in intensity and frequency of extreme weather events in the ZRB, which are exacerbated by climate change. The historic occurrence of extreme events from the Zambezi Environment Outlook of 2015 is presented in Table 2.3.

The basin exhibits high sensitivity of runoff to climate change because it is naturally characterised by low runoff efficiency, low drainage densities and relatively high aridity (Davies, 1989; Cai and Cowan, 2008; Tumbare, 2010). The IPCC (2001) predicts basin runoff to experience a reduction of between 26-40% by 2050, which will result in a decrease in annual streamflow of its rivers. In addition, a gradual decrease in river flows of between 14% to 26% is expected towards the end of the century (Hamududu and Killingtveit, 2016). The semi-arid regions of the Zambezi basin will experience increased water stresses (IPCC, 2007; Beilfuss, 2012). Overall, evidence indicates that the Zambezi will be both drier and more variable, experiencing more prolonged drought periods and more extreme floods (Engelbrecht, McGregor and Engelbrecht, 2009; Shongwe *et al.*, 2009; Engelbrecht *et al.*, 2011; Yamba *et al.*, 2011; Beilfuss, 2012; Schaeffer *et al.*, 2012; Fant *et al.*, 2015; Liechti *et al.*, 2015; Spalding-Fecher *et al.*, 2016; Spalding-Fecher *et al.*, 2017). This presents challenges for water resource use by sectors that depend on it in the basin, especially in regions at the extreme end of the spectrum. The energy sector is one such sector to be negatively affected.

Table 2.3 Occurrence of extreme events in the Zambezi River Basin

2014-2015	Tens of thousands of people in Malawi, Mozambique and Zimbabwe have been severely affected by floods caused by Tropical Storm Chedza, which started in December and continued through February 2015. Malawi has been hard hit by the current floods. More than 200 people have died and 500,000 people displaced. In Mozambique more than 150,000 people have been affected and about 6,000 in Zimbabwe.
2012-2013	Following poor performance in November, good rains were received in the first 10 days of December but dry conditions resumed late January through to May in the southern parts of the Zambezi Basin.
2008-2009	The basin experienced flooding, which displaced thousands of people in Angola, Botswana, Malawi, Namibia and Zambia.
2007	Floods induced by Cyclone Favio impacted on Mozambique and parts of Zimbabwe.
2005-2006	Parts of southern Africa received very heavy rains resulting in flooding that caused considerable infrastructural damage, destroying schools, crops, roads and telecommunications.
2004-2005	Many parts of the Zambezi Basin received below-normal rainfall during the agricultural season. Several riparian states declared national disasters.
2001-2003	Severe drought in the SADC region.
1999-2000	Cyclone Eline hit the region and widespread floods devastated large parts of the Limpopo basin (southern and central Mozambique, southern-eastern Mozambique, parts of South Africa, Botswana and Zimbabwe). In Mozambique alone this affected 2 million people with 650,000 forced to abandon their homes.
1994-1995	Many countries in the SADC region were hit by a severe drought, surpassing the impact of the 1991-1992 droughts.
1991-1992	Worst drought in living memory experienced in southern Africa, excluding Namibia.
1986 – 1987	Drought conditions returned to the region.
1983	This year saw a particularly severe drought for the entire African continent.
1982	Most of sub-tropical Africa experienced drought.
1981 – 1982	Severe drought occurred in most parts of southern Africa.
1967 – 1973	This six-year period was dry across the entire region. Some records show a severe drought.

Source: Zambezi Environment Outlook (2015 p.139)

2.4.2 Hydropower and climate change on the Zambezi River Basin

River flows strongly determine the success and generation of electricity from hydropower. The ZRB exhibits seasonal and inter-annual variability, with future climatic predictions suggesting increased inter-basin climatic variability (IPCC, 2007a; Beilfuss, 2012). This variability has substantial impacts on the generating capacity of existing and future hydropower plants in the basin, especially in periods of extreme weather events like droughts. Assessment of potential impacts of climate change on runoff, reservoir storage capacities and hydroelectric generation on the Zambezi River by Yamba *et al.* (2011) concluded that current and future risks for hydropower in the region were associated with projected dry years, which would likely result in droughts. Yamba *et al.* (2011) showed a gradual reduction in hydropower generation over the next 60 years.

Droughts reduce runoff, followed by reservoir storage capacity, resulting in reduced power generating capacity. The 1992/93 droughts in Southern Africa reduced Kariba Dam's generating capacity by 8% (Chenje and Johnson, 1996). In more recent times, low dam levels in 2015/2016 reduced capacity due to the drought experienced in the region. Kariba Dam, which stores water for hydroelectricity generation to Zimbabwe and Zambia was about 11% full in 2016 (NASA, 2016; ZRA, 2016). This resulted in frequent power outages, with industries reducing their production in both countries (Bloomberg, 2016). A worse scenario was experienced in 2019 when drought hit the region. NASA Earth Observatory images of Lake Kariba show how much the reservoir had receded in December 2019 compared to the same period in 2018 (NASA, 2019). The ZRA reported low dam levels at 8.50% of water usable for power generation (ZRA, 2019). This resulted in massive power cuts of up to 18 hours a day in Zimbabwe and Zambia, with fears of the dam shutting down if water levels continued to decline (Bloomberg, 2019). These scenarios indicate the sensitivity of hydropower to climate variability and extreme weather events, and the frequency of occurrence of these events. It also exposes the risk of Zambia and Zimbabwe's energy security due to their dependence on hydropower from Kariba, whose electricity generation is repeatedly disrupted by climatic events.

Gleick, (1994) emphasises that large reservoirs with a large surface area are prone to substantial evaporative water losses. The Kariba and Cahora Bassa are the largest reservoirs on the ZRB. They experience high evaporative water losses which are expected to increase with climate change as temperatures increase. The study by Beilfuss (2012) of the ZRB showed an 11% reduction in mean annual flows in the Zambezi river due to the evaporation losses from the Kariba and Cahora Bassa dams. These water losses impact the generation capacities of large dams, together with downstream biodiversity that relies on water releases from these dams. This view is supported by Hamududu and Killingtveit (2016), who predict a decrease of 15%-31% in hydropower production potential on the ZRB towards the end of the century as a result of predicted increases in reservoir evaporation and changes in river flows. Humidity impacts evaporative rates of reservoirs. Mukheibir (2007) compared the Congo and Zambezi basins' humidity, suggesting a lower evaporation rate for the Congo Basin than for the Zambezi Basin. He concluded that climate change is predicted to impact the ZRB hydroelectric schemes more than the Congo River Basin. In addition, increases in temperature and rainfall are predicted for both basins, but have different outcomes for the basins' hydrology and ultimately for hydroelectric schemes in the region (Mukheibir, 2007).

Various studies have shown a decline in hydropower in the semi-arid regions of the basin under a drying climate. Using cluster analysis, Conway *et al.* (2017) demonstrated that the Zambezi will hold 73-85% regional hydropower capacity if planned dams are completed. Furthermore, by 2030, 59% of total hydropower capacity in Southern Africa will be in areas that exhibit high rainfall variability, indicating the risk of future concurrent climate-related electricity supply disruption and power rationing for the region (Conway *et al.*, 2017). Fant *et al.* (2015) observed a greater loss of hydropower generation for Zambia, with unmet irrigation demands being experienced in Zimbabwe and Mozambique and worse incidents of flooding in Mozambique due to the predicted impacts of climate change in the basin. The authors used three key performance indicators: flood occurrence, unmet irrigation demand and hydropower generation to study the impacts of climate change on the water resources of Zimbabwe, Malawi, Zambia, and Mozambique. Fant *et al.* (2015) predicted the region to likely be drier, with a small section in the north exhibiting favourable conditions. Spalding-Fecher *et al.* (2017) predict hydropower output to decline by 10-20% in the ZRB under a drying climate, with reductions in Zambia and Mozambique greater than in Zimbabwe and Malawi. Notwithstanding that the above studies used different approaches; they indicate hydropower potential loss under a drying climate in the ZRB. While expansion in hydropower projects improves installed capacity in the basin, it is unequivocable that these efforts are susceptible to climate change, especially with predictions of a drying climate and increases in extreme weather events.

A few studies in the ZRB investigated the impacts of different future climatic scenarios on hydropower production at specific hydropower stations. Hydropower availability and generation is set to decline under a dry climate for Kariba by 15-40% (Spalding-Fecher *et al.*, 2016; Spalding-Fecher *et al.*, 2017). It is predicted to increase under a wet climate by 25-30% after 2030, with Cahora Bassa experiencing a similar trend under dry and wet climates (Spalding-Fecher *et al.*, 2017). Spalding-Fecher *et al.* (2017) found a drying climate for ZRB will reduce production of all existing and new plants by 10-20%, with Kariba being the most vulnerable of the old hydropower plants and Batoka being the most vulnerable of the new plants. Conversely, a wetter climate significantly increases generation at Kariba and most of the new plants, but increases at Cahora Bassa, Kafue Gorge Upper, Chemba and Lupata are not significant. In addition, Spalding-Fecher *et al.* (2016) suggest that expansions of Kariba will experience a 12% reduction in electricity generation and are unlikely to deliver expected increases, even under a favourable climate. In contrast, Cahora Bassa is likely to reach anticipated power generating capacity under a wet climate, but potential is less likely realised under a dry climate. Harrison and Whittington (2002)'s study of the proposed Batoka Gorge hydro project predicted that a 35% fall in the flow of water over Victoria Falls would cut annual power production by 21% and dry season power production by 32%, making it uneconomical. However, this negative outlook has not stopped the project from going ahead, implying factors other than climatic conditions get stronger considerations on hydropower projects in the region.

Cole *et al.* (2014) are of a contrasting view and argue that climate change will not have the worst impacts on Africa's planned investments in hydropower, with a fairly low risk on return in investment with the exception of some areas in the central and eastern regions. Cole *et al.* (2014) suggest this to be the most likely case because most dams were planned and located in water-dense areas or in areas where predicted climatic scenarios were considered. Other studies of the basin have suggested a compromise between energy production and environmental sustainability is possible under the predicted climate change scenarios for development of hydropower plants in the basin (Liechti *et al.*, 2015). A review by Falchetta *et al.* (2019) highlighted the lack of efforts to diversify energy mixes that move away from hydropower in the last three decades in sub-Saharan Africa. Many countries have, instead, incorporated expansion of hydropower plants, which increases their dependence on a technology that is vulnerable to the impacts of climate change. Collectively, East Africa's hydropower potential outlook shows positive impacts of climate change with a negative prediction for West and Southern Africa and uncertainty for Central Africa.

Hamududu and Killingtveit (2016) are of the opinion that the current water resources in the Zambezi basin exceed present demand, a situation that is likely to change with increase in the population of the region. This would result in increased demand for water resources for food production and irrigation, industry and mining, energy, environmental systems, among many other competing needs. Increase in water demand due to climate change will also likely reduce runoff as water allocations will favour other basic water use needs, resulting, again, in reduced hydroelectric generation. The projected wet years also pose a threat of damage to hydroelectric infrastructure due to flooding. A link between weather variability and hydropower production by Barrios *et al.* (2010), who used country-level data, showed that rainfall shortages have adversely affected economic growth in Africa by reducing the share of hydropower in total energy production.

Under the existing climate change predictions and their potential impact on hydropower shown by the studies above, it is highly likely that the Kariba Power Station will be hugely affected by climate change. Losses at Kariba and unmet capacities at the proposed Batoka challenge the country's energy security. This has huge implications on energy security for Zimbabwe and Zambia as they depend on the power generated at the dam that has historically displayed high susceptibility to climatic and hydrological variability.

2.5 Management of the Zambezi River Basin to Support Hydropower and Provide Energy Security in a Climate Change Scenario

Given the transboundary nature of Southern Africa's river systems, a regional collaborative approach is needed to get ahead of the impacts that climate change may have on the region's water resources and energy security. Transboundary cooperation is necessary for successful dam building (Cole *et al.*, 2014). Beilfuss (2012) is of the same opinion, calling for a more strategic approach to dam expansion, considering the potential impact climate change will have on future hydropower production. In addition, there is need for climate change and upstream development demands to be integrated, both from an investment point of view and national and regional electricity planning (Spalding-Fecher *et al.,* 2017). The recurrent crisis in generation at Lake Kariba is an example where shared governance strategies are not in place or fail to support function of the lake. Seasonal low rainfall and excessive water use of the reservoir, together with climate variability, have historically reduced power generation. This has impacted the economies of both Zimbabwe and Zambia and power cuts have had to be implemented (Spalding-Fecher *et al.,* 2017).

Cole *et al.*, (2014) put the success of operation and construction of dams to require co-operative governance given the transboundary nature of Africa's rivers. Political instability and conflict are detrimental to the process. Conway *et al.* (2015) call for institutional integration, especially between agricultural and water institutions, to manage water demands for hydropower. These usually operate separately and in the confines of national agendas. Coordination by different institutions and governments is challenging but crucial, especially in extreme weather events like flooding, to sync strategies and management efforts in disaster management. For example, in the summer rains of 2010/2011, flooding in the ZRB resulted in high water levels in Lake Kariba (Muchuru *et al.,* 2015). Uncoordinated efforts to manage dam water levels upstream of Lake Kariba by opening of spillway gates raised downstream water levels, resulting in more flooding, compromising reservoir management strategies at Cahora Bassa Dam (Muchuru *et al.,* 2015).

At the national and international levels, energy and water systems have been developed, managed and regulated independently. Rasul and Sharma (2016) argue that although interest in adaptation to climate has increased over the years, the focus had remained rather sectoral as opposed to a collective approach (nexus). Similar sentiments are shared by Urwin and Jordan (2008) who go on to argue that sectoral adaptation strategies may result in loopholes as this approach can potentially increase vulnerability or undermine net resilience by decreasing capacity or increasing risks in another place or sector. The above scenario suggests the need for a cross-sectoral approach and integrated strategies in water and energy resource management and planning (Rio Carrillo and Frei, 2009; Hamiche *et al.*, 2016; Mabhaudhi *et al.*, 2016). Furthermore, Hamiche *et al.* (2016) view the water-energy nexus as multidimensional in nature to include environmental, technological, economic, political, and social dimensions which influence each other. They suggest the need for policy on water and energy to consider these dimensions as they are closely linked and impact management of both resources. In the same vein, Mabhaudhi *et al.* (2016) recommend a water-energy nexus approach in regional policy making for water and energy, which is vital for achieving regional water, food and energy security. Spalding-Fecher *et al.* (2017) share similar views and highlight how, for example, there is no evident formal institutional cooperation between the SAPP and ZAMCOM, or other regional water management institutions in the ZRB. A cross-sectoral, multidimensional approach to the management of resources that are transboundary in nature, like water, creates opportunities for best outcomes in a changing climate.

When hydropower cannot meet demand, Spalding-Fecher *et al.* (2017) suggest investment in other capacities or sources of power in situations where hydropower is less available. The World Bank's African Competitive Report 2013 views diversifying energy mix as an approach that ensures energy security, given the over dependence on hydropower. Similar sentiments are shared by Yamba *et al.* (2011) who argue for investing in other renewables and alternative sources of energy. They also advocate for pumped storage hydroelectricity schemes as alternatives to reservoirs and runoff. However, there have been no efforts to diversify the energy mixes in sub-Saharan Africa. Falchetta *et al.* (2019) highlight the lack of efforts to diversify energy mixes that move away from hydropower in the last three decades in sub-Saharan Africa. Instead, they have focused on expanding hydropower plants which are susceptible to climatic variabilities. This suggests an issue of governance and political will to explore alternatives. Similar sentiments are shared by Cole *et al.* (2014), who suggests that political and fiscal considerations take precedence when siting dams. Spalding-Fecher *et al.* (2017) adds on by highlighting the continued focus on expansion of hydropower for electricity for Zimbabwe through the Batoka Hydropower project although its projected to fail to meet capacity. Yamba *et al.* (2011) suggest inter-basin water transfers to help mitigate water shortfalls for power generation in sub-basins that contain hydropower installations. The benefits of this approach are mainly felt by runoff river hydro schemes. Tumbare (1999; 2005) agrees on the feasibility of inter-basin transfers for the ZRB given the transboundary nature of the basin, which requires a basin-wide approach to water management in the region.

Mukheibir (2013) suggests moving towards adapting to the variability of climate change by designing and managing climate change resilient hydropower systems, an approach shared by Goulden *et al.* (2009), where adaptation of river basin management to climate change secures prosperity. These climate resilient hydropower systems would be tailor-made for a wide range of patterns and a magnitude of climate impacts (IEA, 2020). Government would play a leading role, financing, providing technical support and developing legislation that integrates climate resilience considerations. Such systems will minimise losses due to the impacts of climate change. Improvements in data collection, sharing and documentation, together with developing modelling capacity for climatic scenarios, weather, water and energy use, help improve the chances of achieving the above securities. However, application of the data collected is needed for best outcomes in managing the ZRB. Conway *et al.* (2015) argue that there is no noticeable evidence of this approach in water resource management in Southern Africa as data collected is not applied in operational use of water resources in the region. This is an example of opportunities lost to improve present water resource management and underutilisation of the information available for informed decision-making processes and improvement of energy security in the region.

2.6 Climate Change-Water-Energy Nexus and Urban Livelihoods

Urban areas inherently exhibit high risk to the impacts of climate change. Two thirds of the world's urban population come from low and middle-income countries that lack the adaptive capacity to build resilience to the impacts of climate change (UN, 2006). High levels of vulnerability and low adaptive capacity across the African continent have been linked to poverty, among other things. Until recently, many local governments have been more focused on poverty reduction than climate change adaptation as it was viewed as a means of reducing the vulnerability of the urban poor (Ka Lee, 2008). There has been less focus on impacts on sources of livelihoods of the urban poor due to climate change. The informal sector is a source of livelihood for the urban poor whose success could potentially be affected by climate change. Building resilience and improving the adaptive capacity of this sector preserves its function as a source of livelihood for the urban poor. Energy insecurity due to a climate change-water-energy nexus directly impacts the livelihoods and productivity of informal businesses through unavailability of electricity.

2.6.1 Defining and characterising informal urban livelihoods

The informal sector was well established by the 1960s, with Hart (1973) introducing the term 'informal sector', making reference to Ghana's towns (Potts, 2008). The concept of the informal sector was internationally recognised in 1998 by the ILO in Kenya. Informality was defined as "a way of doing things characterised by ease of entry, reliance on indigenous resources, family ownership, small scale operations, labour intensive and adaptive technology, skills acquired outside the formal sector, unregulated and competitive markets".

Chen *et al.* (2013) defines the informal sector through dominant schools of thought. The authors speak of the dualist school of thought which believes the informal sector exists as a result of slow economic growth or fast population growth that cannot cater for all; hence job opportunities are scarce and the informal sector takes up the surplus labour. The structuralist school of thought looks at the informal sector as entities that create a competitive environment with the formal sector, reducing labour and input costs in the process. The legalist school of thought views the informal sector as micro-entrepreneurs who want to cheat the system and avoid the expenses and time of formal registration. In a review of literature on the informal sector, Gërxhani (2004) put together a criteria to define the sector. The informal sector fell into the political, economic or social criteria with sub-criteria. The political criteria included government regulation, illegal activities and national statistics. The economic criteria, which is the most popular, covered labour market, tax evasion, size of activity, professional status, regulation or registration of activity and national statistics. The social criteria included social networks, ease of entry, autonomy, flexibility and survival.

Other scholars have defined informality in terms of the absence of characteristics that belong to the formal sector such as regular employment, social benefits and union protection (Eapen, 2001; Njaya, 2015). In Zimbabwe, only domestic workers are unionised under the Zimbabwe Domestic and Allied Workers Union

(ZDAWU), which is affiliated with the Zimbabwe Congress of Trade Unions (ZCTU). The informal economy (or sector) is defined by Hart (2007) as a set of economic activities that take place outside the framework of bureaucratic public and private sector establishments. It is also a form of unofficial earning strategies with entrepreneurs that desire to escape state regulations (Edusa and Tribe, 1992). However, Njaya (2015) points out that not all informal businesses evade paying tax or purposefully infringe on labour regulations. He argues that their revenue is so low that their businesses cannot afford to pay taxes and government does not recognise them because they are small, hence, it does not enforce regulations on them. In addition, Njaya (2015) indicates that the government of Zimbabwe requires all informal businesses to register and pay presumptive tax, but he found that about 2% were registered with the Zimbabwe Revenue Authority (ZIMRA) for presumptive tax. This is likely because it is still unaffordable for informal businesses.

The 17th International Conference of Labour Statisticians (ICLS) defines informal employment as:

> *all jobs carried out in informal enterprises as well as in formal enterprises by workers, and especially employees, whose employment relationship is, in law or in practice, not subject to national labour legislation, income taxation, social protection or entitlement to certain employment benefits (advance notice of dismissal, severance pay, paid annual or sick leave...) because of non-declaration of the jobs or the employees, casual or short duration jobs, jobs with hours or wages below a specified threshold...place of work outside premises of employer's enterprise (outworkers), jobs for which labour regulations are not applied, not enforced, or not complied with for any other reason. (ILO, 2003)*

In Zimbabwe, Informal Sector Operations (ISOs) include all enterprises not registered under the Companies Act or the Co-operatives' Act, together with those not assessed for taxation by central government (Paradza, 1999). The National Micro, Small and Medium Enterprises Policy Framework of Zimbabwe acknowledges the informal sector and states that it is found in all sectors of the economy, predominantly lacks accountability, operates outside of the law and is not registered or licensed. The policy intends to formalise the informal sector which is largely constituted of micro enterprises (Government of Zimbabwe, 2014). Charmes (2012) states that "employment in the informal economy comprises all persons (whatever their employment status) working in informal enterprises, plus all persons working informally in other sectors of the economy, that is, formal enterprises". Hence, the informal economy is constituted by the formal and informal sector, with some Small and Medium Enterprises (SME)s and Micro, Small and Medium Enterprises (MSMEs) being informal businesses. Chen *et al.*, (2013) illustrate (Figure 2.4) how the informal sector and informal economy merge and which group of workers belong to which segment.

The informal sector covers a wide range of labour market activities which are either coping strategies of individuals, or families in economic environments where earning opportunities are scarce. Self-employment is most widely practiced in sub-Saharan Africa, with own-account workers making up the largest group in that category (Njaya, 2015; Chen *et al.*, 2016). Chen *et al.* (2016), for example, point out that self-employment constitutes 53% of informal employment in sub-Saharan Africa. Stuart *et al.* (2018) mention how own-account enterprises dominate informal businesses in developing countries. In a study in Zimbabwe, the ILO (2017) found 94.9% of women in the informal sector constituting own-account workers. Charmes (2012) adds that women in informal businesses are usually self-employed.

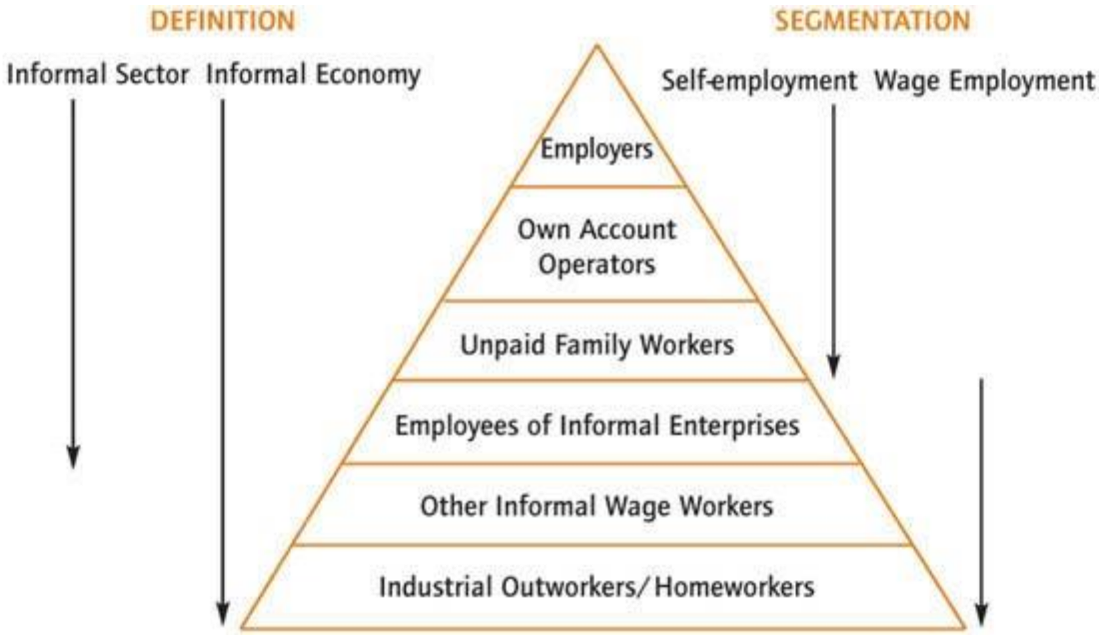

Figure 2.4 Definition and segmentation of the informal economy
Source: Chen *et al.* (2013, p.24)

Chirisa (2009) classified the urban informal sector in Zimbabwe using six criteria: spatial location, mode of support, composition of operators, nature of net profit and returns, nature of goods and services provided and by whether or not value was added in the informal business. Spatial location included neighbourhoods based close to or in conventional industrial sites and in the Central Business District (CBD). Mode of support included family-based, institutional, organisational and social alliances, while composition of operators included sole proprietors, employing others and co-operatives. Net profits and returns where high, low and medium, nature of goods and services provided included food, arts and crafts, clothing, labour, and value added included whether value was added or not. This speaks to the numerous informal businesses practiced in Zimbabwe.

Others have described the informal economy with reference to places where informal work is carried out. Becker (2004) came up with four categories, namely, home-based workers, street traders and vendors, seasonal or temporary site workers and those who work between the street and at home. This indicates that home-based informal work has been practiced considerably in many regions of the world. Home-based workers are usually self-employed or waged employees who make products or provide services in and around their own dwellings (Horn, 2009; Chen and Sinha, 2016). The activities of home-based businesses differ depending on the type of neighbourhoods they are established in. Chen and Sinha (2016) discuss factors like access to transport, capital and proximity to the formal sector as usually being a concern for successful running of home-based businesses. Therefore, access to markets is important and determines the success of home-based informal businesses. In addition, Magaisa and Matipira (2017)'s survey in Bulawayo, Zimbabwe's second largest city, found access to markets as a setback to the success of SMEs. Home-based enterprises (HBEs) are not restricted to low income groups. Kazimbaya-Senkwe (2004) found HBEs in all housing categories, whether high or low income in Zambia. Furthermore, the home is an indispensable productive asset for HBEs. Chen *et al.* (2016) elaborate by highlighting that the size of the house determines flexibility in doing home-based work while sharing the same space with family. It is used as the site for selling and marketing produce, as alluded by the ILO (2017).

Some studies have pointed out that home-based workers have few economic opportunities and have the least security and lowest earnings among informal workers (Horn, 2009; Chen and Sinha, 2016). This is a characteristic of informal business and Njaya (2015) elaborates by indicating how they are vulnerable to exploitation as they cannot appeal to courts for legal assistance pertaining to issues such as unpaid jobs or services. The author goes on to argue that this has encouraged some informal businesses to register and formalise. Other benefits absent in the informal sector include maternity leave for women and social protection because of the absence of formal contracts for those employed informally (ILO, 2017). This has forced women to create their own types of social protection; for example, in Zimbabwe, savings clubs commonly called *mukando* were observed by the ILO (2017). Home-based workers possibly save on transport costs, rentals and time; hence, home-based businesses are attractive to women (Horn, 2009; Chen and Sinha, 2016). They perform their household work and run home-based informal businesses simultaneously; however, their contribution to the economy is not captured or recognised. Chen and Sinha (2016) argue that the work of women in home-based informal work is often seen as an extension of their domestic work. They are usually unaccounted for in national statistics, with challenges in classifying home-based work still present.

2.6.2 Growth and role of women in the informal sector

Literature suggests that the informal sector in poor countries grew as rapid urbanisation in poor countries did not tie in with significant growth in the formal sector, hence, jobs in the formal sector were scarce (Potts, 2008). Nonetheless, the sector has expanded. Brown and McGranahan (2016), for example, point out that the informal economy is not only large, especially in providing employment, but continues to grow. Numerous studies have linked growth of the informal sector in less developed countries with the period after Structural Adjustment Programmes (SAPs) by the IMF and World Bank had been implemented, from about the 1980s. The sector had an insignificant role to play before this period, as the formal sector was booming immensely in urban areas (Cobbe, 2002; Chirisa, 2009; Sparks and Barnett, 2010). This was the case in Zimbabwe. As government spending was greatly cut, job losses rose and economic hardships grew, forcing urban populations to develop diversified livelihood strategies as the economy shifted (Chirisa, 2009; Njaya, 2015). The above trend insinuates that as economies of countries struggle, the informal sector grows as it tends to swell during periods of adjustment when employees are laid off. This is supported in literature (Calvès and Schoumaker, 2004; Yuki, 2007; Sparks and Barnett, 2010; Benjamin and Mbaye, 2014; Njaya, 2015) and explains the continued growth of the informal sector in Zimbabwe which often goes through waves of economic challenges. Furthermore, a study by the IMF found Zimbabwe to have one of the largest informal economies as a percentage of its economy in the world (Medina and Schneider, 2018).

The role of the informal sector in terms of job creation cannot be overstated. In 2009, the World Bank estimated that about two thirds of all employees work in the informal sector, with Haan and Maclean (2006) stating that the informal sector provided between 50-75% of employment. The informal sector is a source of livelihood for many urban poor populations and is one of the largest employers in most African cities (Karekezi and Majoro, 2002; Chirisa, 2013). About 93% of new jobs created in sub-Saharan Africa during the 1990s were in the informal sector (Chen, 2001; 2016). Charmes (2012) estimates about 80% of total employment in sub-Saharan Africa is in the informal economy. Schneider *et al.* (2010) allude that the informal sector contributes to income and employment of the urban population. The continued growth of this sector has seen its perception worldwide change as it is now seen as an opportunity to tackle poverty reduction and economic growth (Tokman, 1989; Rakowski, 1994). The informal sector provides means of alleviating poverty in urban areas as most people that practice the trade are the urban poor (Chirisa, 2013). The small income earned by a household on a regular basis is most welcome and draws the line between sleeping hungry or full.

The informal sector plays a huge role in African economies by contributing to the GDP and creating employment (Benjamin and Mbaye, 2014). Mbiriri (2009) points out that 70% of India's GDP comes from the informal sector. In the same vein, MSMEs contributed 60% of GDP in Zimbabwe's Medium-Term Plan (2011-2015) (Ministry of Economic Planning and Investment Promotion, 2011). In spite of these accessions, other studies do not see the contribution the informal sector makes to GDP. Schneider *et al.* (2010), for example, have seen a marginal or uncertain contribution of the informal sector to GDP, but point out the sector's contribution to income and employment. People in the informal sector are mainly located in designated residential areas where the urban poor live. Chirisa (2009) observed that informal traders are usually located in designated municipal areas in the city centre or along pavements, as is the case in Harare, Zimbabwe's capital city. In Harare's high-density areas, municipal and cooperative cubicles house informal traders (and some registered traders) like Glen View Furniture Complex, Siyaso and Gazaland, locally called home industries (Njaya, 2015).

The informal sector is dominated by women, with 84% of employed women belonging to the informal sector (Chirisa, 2013; Benjamin and Mbaye, 2014). Charmes (2012) is of the view that women in the informal sector are likely to be self-employed. Chirisa (2013) adds that the majority of women in the informal sector are home-based or vendors. The ILO (2017) found women involved in various trades from cross border trading, vending, services, manufacturing, mining and stone quarrying. Similar trades were observed by Chirisa (2013) and Chen and Sinha (2016). Women are also exploring male dominated trades like welding, brick moulding, stone quarrying, mining and furniture manufacture in Zimbabwe (ILO, 2017). Despite the gendered landscape of some informal trades, the participation of women in some male dominated trades highlights the severity of unemployment or income sources of urban households in Zimbabwe.

Studies indicate that most women are normally self-employed or unpaid home-based workers (Chen, 2001; Chirisa, 2009; Charmes, 2012). This is usually a neglected aspect of the contribution of women to the informal sector as home-based work seldom gets recorded (Hassan and Azman, 2014; Chen and Sinha, 2016). Some authors, for example Eapen (2001) and Fapohunda (2012), believe that women struggle to get employment in the formal sector because of household responsibilities, social and cultural barriers and lack of formal training and skills. Despite some literature suggesting that women in informal work are uneducated, the ILO (2017) study found 67.7% of women in informal work had at least attained secondary education. However, Gindling and Newhouse (2014) claim that own-account workers fall between educated and least educated.

Trading in the informal sector comes with challenges for women. Several studies have acknowledged that women have weak bargaining power, even in the formal sector where they have traditionally occupied low-income jobs that require minimal skills due to limited access to education (Cobbe, 2002; Ombati and Ombati, 2012; Chigudu, 2018). These studies go on to suggest that this limits women's access to credit, putting a threshold on how far their businesses can go. Higher interest rates are charged on loans because women seldom provide collateral for loans. In addition, women struggle to meet lending terms, with some having been in informal business for a short period. Lack of access to credit leaves women in low-end income generating activities like vending, as it is easier to enter those trades (ILO, 2017). In the same vein, other researchers point out that women have an inferior legal status bound by cultural practices that leave them with roles around the home like raising children (Moghadam, 2007; Chen and Sinha, 2016). There is agreement that this usually leaves women with no choice but to combine their HBEs with their domestic roles to earn these important sources of livelihood (Carr *et al.*, 2000). Their economic contribution is usually unaccounted for because they themselves do not see their home-based work as work. In addition, enumerators are seldom trained to identify them in national surveys like population censuses (Chen and Sinha, 2016). Chirisa (2013) points out that the closest women in the informal sector get to being registered is through payment of hawkers' licenses or monthly rentals to council to use designated trading areas. However, they are usually subjected to raids by local authorities as many cannot afford licenses or tax (Njaya, 2015; ILO, 2017).

Literature implies that the employment opportunities created by the informal sector allows the urban poor to sustain their livelihoods and contribute to economic growth, poverty reduction and empowerment of women. Development of adaptive strategies that protect this source of livelihood from shocks like the impacts of climate change and energy insecurity nexus is necessary.

2.6.3 Energy use and urban livelihoods

Urban cities are energy intensive as they consume about two thirds of global final energy use (REN21, 2020). Studies have focused on an increase in energy demand in cities due to rapid urbanisation, especially in less developing countries (Madlener and Sunak, 2011). However, research that further looks at how climate change might potentially impact energy availability to these areas where demand keeps increasing is scarce, especially in less developed nations.

Brew-Hammond (2010) is of the opinion that to improve income generation in African communities, emphasis should be placed on productive uses of energy for income generation. His view implies that sectors like the informal sector could improve livelihoods of the urban poor if the energy required in these sectors is secured.

Energy consumption in informal sector enterprises is characterised by low to medium energy intensity compared to other high intensity formal sectors like the heavy industries (Karekezi and Majoro, 2002). Ihrig and Moe (2004) claim the informal sector to be labour intensive and not capital intensive as the scale of production is small, suggesting low energy use. However, this does not diminish the importance of availability of energy to this sector. A few studies have highlighted how the livelihoods of people in the informal sector heavily depend on availability of electricity for them to perform their trades and earn much need income (Karekezi and Majoro, 2002; Chen, 2016). Energy availability drives and grows this sector as a lot of the trades in the informal sector are energy dependant. Chen and Sinha (2016) found that garment makers in home-based informal work in Pakistan expressed the same sentiments. Erratic power supply stopped productivity, which affected their bottom-line as targets were unmet. They had to work overtime when power got back to make up for lost time. The garment makers highlighted substitution in the absence of electricity affected their income as it was usually costly. Use of manual equipment was usually tedious and seldom produced similar quality products. Absence of electricity in energy dependent informal trades has devastating effects for the informal sector. It halts production, resulting in unmet or delayed production targets, loss of customers and, subsequently, loss of income.

Several studies have used the levels of pollution as indicators of energy consumption, especially in the informal sector, as pollutants are by products of energy consumption (Biswas *et al.*, 2012 ; Elgin and Öztunali, 2014; Basbay *et al.*, 2016). This suggests that informal sector size is highly related to pollution levels. A relationship between informality and energy intensity was found by

Elgin and Öztunali (2014) and Basbay *et al.* (2016), reiterating the importance of electricity in the informal sector. Although the above studies were mainly focused on the relationship between informal sector size and pollution levels, they expose the energy dependence of the informal sector. Therefore, securing energy for populations that earn their livelihoods through the informal sector builds the resilience of the urban poor to the impacts of climate change and energy security nexus.

2.6.4 Institutional influence in urban livelihoods

There is agreement on the important roles institutions play in adaptation measures, especially local institutions as their adaptation strategies impact the vulnerable populations in communities, mainly the poor (Hardoy *et al.*, 2001). An institution that overseas climate change was set up in 1992 at the UNFCCC. Implementation of regulatory frameworks necessary for public health and safety was identified by Hardoy *et al.* (2001) and Dodman and Satterthwaite (2008) to fall into the hands of municipal governments in low and middle income nations. Hardoy *et al.* (2001) give a broader perspective on how pro-poor local government strategies that aim at building resilience of the urban poor are necessary because low-income groups are usually made up of the groups most vulnerable to disturbances. They argue that these approaches consider different scenarios that contribute to poverty and marginalisation of different groups in urban communities like gender. These strategies and support could benefit women in the informal sector as they dominate the informal sector. Dodman and Satterthwaite (2008) propose that resilience to climate change becomes more effective when urban governments take charge in implementing strategies to adapt and respond to the impacts of climate change due to their spatial proximity to these disturbances. Overall, there seems to be agreement on the importance and effectiveness of the local level role of government in assisting the vulnerable urban population with the impacts of climate change.

National government provides the legislative, financial and institutional basis within which urban authorities, the private sector, civil society and other stakeholders can act to adapt to climate change as identified by Hardoy *et al.*, (2000) and Dodman and Satterthwaite (2008). However, sectoral funding usually comes from international non-governmental organisations (NGO)s and donor organisations as they have the resources and expertise to support and develop adaptation activities directly (Tanner *et al.*, 2009). In Zimbabwe, the National Climate Change Office, under the Ministry of Environment, Water and Climate is funded by the United Nations Development Programme (UNDP) and communicates with the UNFCCC. Under the Office of the President and Cabinet, falls the National Climate Change Task Team. This body is responsible for producing the National Climate Change Response Strategy. The National Climate Change Steering Committee then includes other government and civil society interests (Dodman and Mitlin, 2015). Civil society also has a role to play in implementing strategies that reduce the impacts of climate change on urban populations as they are the voice of the people. Collectively, these studies outline the separate levels of institutional influence in climate change adaptation of urban spaces.

Chigwenya and Mudzengerere (2013), highlight the legislative and financial role government has played in the informal sector by creating policy frameworks and enacting laws to fund and develop the informal sector. After years of neglecting the informal sector and not seeing its economic value, the government initially stimulated the sector as a source of livelihood by developing the Small-Medium Enterprise Policy framework in 2002 and has continued with similar pieces of legislation in a bid to assist the informal sector (Chigwenya and Mudzengerere, 2013). In the informal space, the Ministry of Small, Medium Enterprises and Cooperate Development (now Ministry of Tourism and Ministry of Women Affairs, Community, Small and Medium Enterprise Development) was formed to promote SMEs, supported by what is now Small and Medium Enterprises Development Corporation (SMEDCO), which provides finances and helps build the capacity of SMEs (Chigwenya and Mudzengerere, 2013; Njaya, 2015). However, the ILO (2017) highlighted that the ministry and its support focus on registered enterprises, eliminating assistance and financing of informal businesses as most cannot afford to get registered and hence remain unrecognised, lacking financial support. Chigwenya and Mudzengerere (2013) indicated that government creates an enabling environment to avail funds from donor and cooperate communities to the informal sector. Furthermore, Njaya (2015) highlights that NGOs provide financing and training in the informal sector and adds that growth of SMEs is limited by access to markets, limited infrastructure and technology and high costs of credit and finances.

2.7 The Gaps in Climate Change and Energy Research

Climate change and its unpredictability has the potential to increase pressure on water and energy as it becomes more variable and scarcer in availability. Many papers on the energy-water nexus have been written from the USA's perspective (Gleick, 1994; Feeley *et al.*, 2008; Mielke *et al.*, 2010; Chandel *et al.*, 2011; Liu *et al.*, 2015). The majority of them have been carried out under the US Department of Energy, a sentiment shared by Tan and Zhi (2016). Studies in the USA identify the existence of the nexus but stress more on the need to invest in technologies that make thermal energy sources more efficient or integrated water management than developing cleaner renewables as alternatives (Feeley *et al.*, 2008; Chandel *et al.*, 2011).

A few studies have extensively reviewed literature on climate change and hydropower globally and in the region (Lumbroso *et al.*, 2015; Mabhaudhi *et al.*, 2016; Shu *et al.*, 2018; Falchetta *et al.*, 2019). Regional studies have mostly looked at climate change and energy interactions within the entire ZRB (Yamba *et al.*, 2011; Beilfuss, 2012; Spalding-Fecher *et al.,* 2017). A few have scaled down their research to local sub-basin level. Scaling down allows for a better understanding of the direct impacts of climate change on water resources and energy security at country level. This approach has been criticised by van Vliet *et al.* (2016), who believe geographical distribution of climatic factors often exceeds country or state boundaries, hence, large-scale studies are more suitable. However, localised studies are still relevant as they consider other local factors or patterns that are usually eroded in large scale research. Shu *et al.* (2018) agree on the need to narrow down studies from large scale to specific local hydrographic settings in research. Although hydrological and climatic change threatens the ZRB as a whole, probing impacts at country level allows for improved understanding and context-relevant implementation of mitigation measures.

Literature on the energy-water nexus rarely looks at water use across all energy sectors. There are few studies on the interactions of water with solar, wind and geothermal energy (Tan and Zhi, 2016). Schaeffer *et al.* (2012) are in agreement and call for studies that differentiate climate change impacts on different energy sectors as these remain understudied and unexplored. Mabhaudhi *et al.* (2016)'s review of the water-energy nexus of Southern Africa investigated this area and found statistics for water demands poorly documented with varying figures. They, however, found coal-fired thermal power plants to have the highest water withdrawal in the region, with hydropower having the highest demand for water and photovoltaics (PV) and wind carrying the best water efficiencies. Nonetheless, securing adequate water supply is a concerning issue in the energy sector, especially in light of the predicted impacts of climate change on water resources (Busby, 2007). As world populations and economies continue to grow, climate change and its impacts on water resources further affect energy demand (van Vliet *et al.*, 2016a). However, considerable research on climate change and its impacts on water resources seems to have been more directed towards the effects on agriculture and food security (Fischer *et al.*, 2007; Frumkin *et al.*, 2008; Brown, Hintermann and Higgins, 2009; Negin *et al.*, 2009) with fewer studies on the impacts on energy.

Research has also been limited to the impacts that climate change will have on energy supply as infrastructural damage by extreme weather events will cut supply in many regions, especially cities (IPCC, 2007a; IEA, 2010; Davis and Clemmer, 2014). These types of studies are predominantly the focus of research on climate change impacts on energy in cities. The unpredictability of climate change also results in unpredictability of its impacts on energy outputs of many energy generating technologies. This will impact available energy, which may affect supply. Altered precipitation and reduced reservoir storage due to evaporation will impact hydropower generation or yields in crops grown for biofuels (Bates *et al.*, 2008). In addition, efficiencies of thermal power generation stations are reduced in extreme climatic events (Bates *et al.*, 2008; IEA, 2010b). As climate change impacts water availability due to reduced precipitation, increases in temperature and increased rates of evaporation in water bodies whose river flows would have been depleted, more electricity will be required to pump water over long distances to areas such as cities, where it will have become scarce while demand is high (Bates *et al.*, 2008). Other techniques like desalination to produce freshwater from oceans will require more energy use. This, coupled with extreme temperatures and hotter climates, will increase the demand for energy for heating and cooling (Bates *et al.*, 2008).

Many papers on the vulnerability of the urban poor to the impacts of climate change focus on the direct impacts of extreme weather events on urban populations, or vulnerabilities due to lack of resilient infrastructure or services to the poor in urban areas (Carmin *et al.,* 2012). There has been less focus on impacts on sources of livelihoods of the urban poor due to climate change. In addition, research on climate change impacts on urban livelihoods in the context of Zimbabwe is hard to find. Furthermore, literature on climate change impacts on livelihoods is populated by climate change impacts on rural livelihoods than urban livelihoods. This could be due to the agrarian based livelihoods in rural areas. Nonetheless, it does not diminish climate change impacts on urban livelihoods. Also, climate change-energy studies are populated by research that looks at mitigation efforts rather than impacts (Haines *et al.*, 2007; IPCC, 2007; Bernard, 2014; van Vliet *et al.*, 2016). Moreover, studies that look at the climate change-water-energy nexus and urban livelihoods are scarce.

The informal sector covers a broad range of activities and has been widely studied globally and in Africa. However, studies that focus on home-based informal work in cities are limited. Most research on home-based informal work is populated by Asian cities (Chen, 2001; Chen and Sinha, 2016), with few studies in African cities (Kazimbaya-Senkwe, 2004). While many studies mention their existence (Chen, 2001; Becker, 2004; Kazimbaya-Senkwe, 2004; Chirisa, 2009; 2013; Horn, 2009; Charmes, 2012; Hassan and Azman, 2014; Chen and Sinha, 2016), there are limited household surveys that characterise the people and the informal enterprises of home-based trades. Home-based work is often unaccounted for in labour force surveys and population censuses as it is rarely recognised as work. In addition, it is mainly practiced by women and seen as an extension of their domestic work (Chen and Sinha 2016). Studies on home-based informal work in Zimbabwean cities are also scarce. While other authors, like Chirisa (2009) and Njaya (2015), characterised informal businesses in Zimbabwe, their studies did not focus entirely on home-based informal work. Moreover, there are limited studies that focus on electricity use in the informal sector, particularly in the Zimbabwean context. Therefore, home-based energy dependent informal work is understudied in Zimbabwe.

2.8 Conceptual Framework

Until recently, most assessments of the impact of climate change on urban cities have focused on the direct infrastructural damage extreme weather events would have on vulnerable urban populations who lack the capacity to adapt to the impacts of climate change (Carmin *et al.*, 2012). There has been little considerations on how climate change impacts on urban livelihoods as the studies have largely been on climate change impacts on rural livelihoods. Furthermore, studies that look at the impacts of climate change on energy focus how energy supply will be cut through infrastructural damage, especially in cities (Davis and Clemmer, 2014). There is less focus on how climate change would impact on energy generation especially for technologies that are water dependent like hydropower. With climate change predictions by the IPCC (2018) indicating increases in variability of temperature and precipitation, which affect availability of water resources for energy generation, it poses a threat to energy security for regions that depend on water dependent generating technologies like hydropower. It highlights how climate change, water and energy are inextricably interconnected. Understanding the trends and relationships that exist between these variables is important as it allows for a better understanding of how they impact spaces like urban system.

Cities are the focus of economic activities and are the origins of most of the global demands of resources like water and energy. They are also display high risks to the impacts of climate change especially for populations that lack the adaptive capacity to respond to the impacts of climate change like the urban poor (Carmin *et al.,* 2012). In a changing climatic environment, long term trends and the relationship between climate change, water and energy has a potential bearing on energy security, especially for nations that depend on hydropower for electricity. Energy security is crucial in cities that as they are centres of energy consumption. Therefore, this conceptual framework focuses on 1) Climatic (temperature and precipitation), hydrological (runoff) and hydropower generation trends and relationships to establish a climate change-water-energy nexus; 2) How a climate change-water-energy nexus impacts on urban livelihoods? 3) How vulnerable groups adapt to the impact of energy insecurity due to a climate change-water- energy nexus? 4) The role of institutions and policy makers in the climate change-water-energy nexus and its impacts on urban livelihoods. Figure 2.5 illustrates the intricate linkages that exist between the climate change, water and energy. It shows how climate change drives changes in temperature and precipitation(A) affecting water resources (B), which in turn affect water dependent energy technologies like hydropower (C). Climate change drivers play a substantial role in this conceptual framework, as having overall impact on water resources, that affect hydropower generation through river runoff, establishing a climate change-water-energy nexus as shown in D. Temperature and precipitation affect quantity, quality and timing of water supply for energy production. Climate change acts as a major driver of increasing temperature and

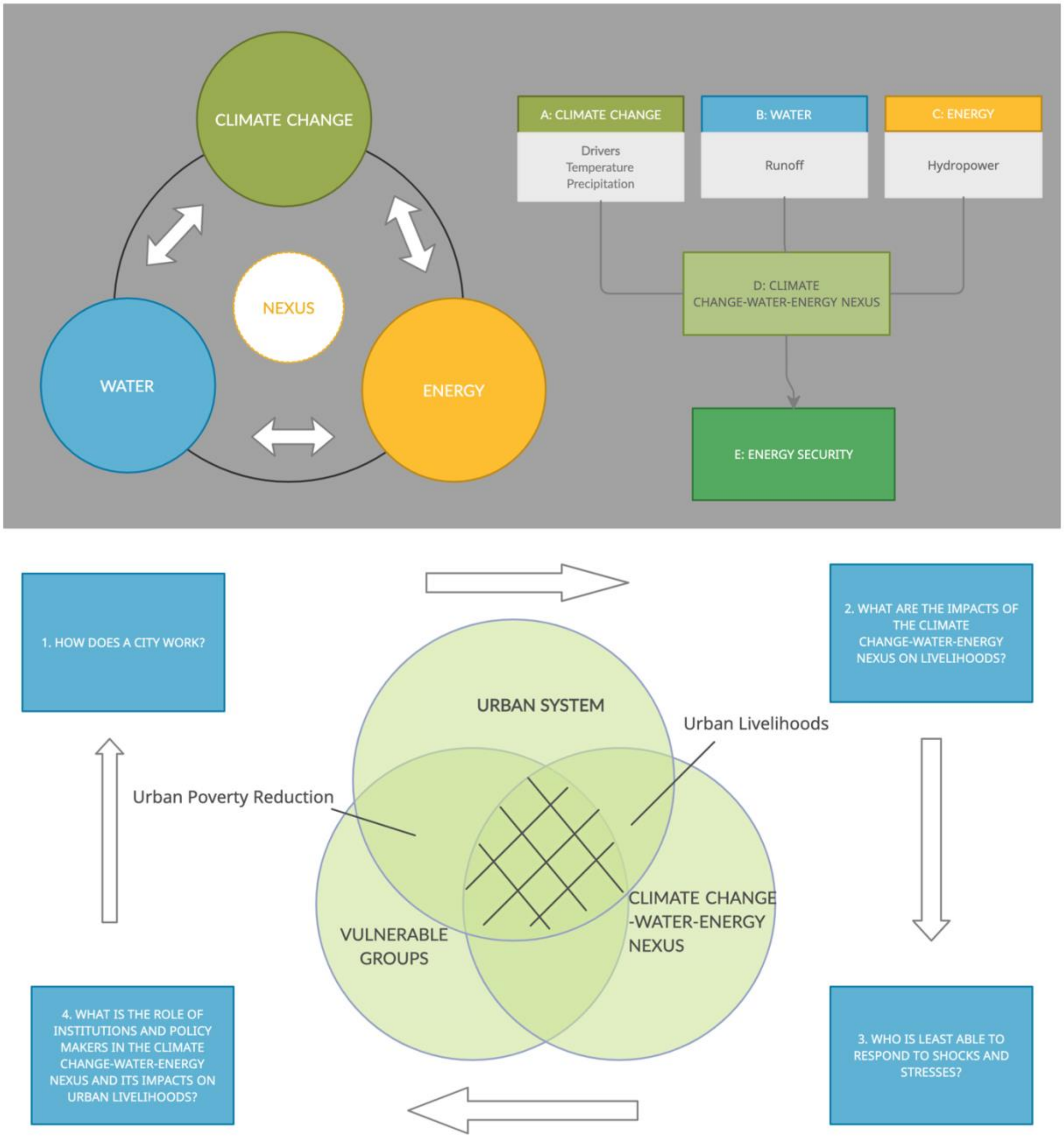

Figure 2.5 Conceptual framework of the climate change-water-energy nexus and its impact on urban livelihoods.
Source: Memory Reid (2020); Modified from (Da Silva *et al.*, 2012)

changing precipitation. Related frequent flooding or dry spells could significantly reduce water supply and increase water stress, having long term impacts on water resource use for sector like energy generation as illustrated in figure 2.5. It has a bearing on energy security.

The climate change-water-energy nexus exists in an urban system. For a nation that depends on water dependent energy technologies like hydropower, urban spaces are impacted on by a climate change-water-energy nexus. It creates energy insecurity for an urban system. The framework adopted is modified from Da Silva *et al.* (2012), who highlighted how climate change impacts an urban system and how vulnerable groups are affected. The framework is modified by replacing climate change with a climate change-water-energy nexus. In an urban system urban livelihood vary with a number requiring energy and are indicated in the framework. Electricity dependent informal urban livelihoods fit this criterion. However, the groups likely to struggle in an urban population are the urban poor. These are the vulnerable groups, that struggle to adapt to the impacts of a climate change-water energy nexus in an urban system. These are represented by the shaded are in the figure 2.5 and are of interest to the study. Therefore, the framework will be used to investigate how urban livelihoods operate in an urban space. It goes on to investigate how these livelihoods are impacted on by the climate change-water-energy nexus. It then investigates how these urban likelihoods respond to shocks brought about by energy insecurity due to a climate change-water -energy nexus. Local governments' focus has for a long time been on poverty reduction for the urban poor, with little attention on climate change adaptative and resilience (Ka Lee, 2008). The study therefore looks at the role of institutions and policy makers in the climate change-water-energy nexus and its impacts on urban livelihoods. The performance and management of the overall urban system is crucial for cities to effectively adaptive to the impacts of climate change (Brown *et al.,* 2012). This emphasises the role of policy makers in climate change, water resource management, energy security and urban livelihoods.

An improved understanding of the complex relationships between climate change, water, energy and urban livelihoods helps create integrated resource management strategies to obtain multiple benefits to adapt to climate change. It encourages cross-sectoral collaboration to improve coordinated responses to climate change. The proposed conceptual framework is the first step to help us better understand the complex and dynamic interactions between climate change, water resources, energy security and urban livelihoods to develop strategies for improved management of these elements. It identifies their synergies to provide an integrated conceptualisation of how climate change affects livelihoods of the urban poor in Harare Zimbabwe.

2.9 Conclusion

Existing studies of the ZRB suggest a decrease in future discharge for the region. The majority look at climatic scenarios without considering other water resource demands, allocation and development demands of the region. Very few studies have focused on the implications of ground water in a climate change scenario and how it ultimately impacts water resource availability in the region. Research on climate change and energy is limited to energy supply disturbances due to extreme weather events, which are mainly focused on coastal areas. More research is needed on the impacts of climate change in relation to the water-energy nexus.

The studies of the basin above support the view that climate change will have an impact on water resources and hydropower generation in the basin. The same literature suggests the existence of a climate change-energy security nexus for sub-Saharan Africa. Research on the impacts of climate change on hydropower needs to be expanded. It is unclear what effects climate change induced variations in precipitation and temperature will have on hydropower generation, given the high climatic variability of the region. This calls for more robust and improved studies and modelling techniques to improve understanding and predictability of these climatic patterns and how they impact water resources and energy security.

Climate change will affect the water-energy nexus by changing the number and availability of freshwater resources and increasing demand for both electricity and low-carbon emitting renewable water intensive energy solutions. Challenges arise when trying to predict future impacts of extreme weather events on energy. One method used is using past experience to model and predict future climate change vulnerability of energy systems (Mukheibir, 2013). However, the approach became unreliable as the weather extremes have become highly variable with increased intensity (Schaeffer *et al.*, 2012). It is also unclear how much climatic studies and models are incorporated into the decision making process during the planning stages of dams. Cole *et al.* (2014) suggest that dam decision processes are dominated by political and fiscal considerations, lobbying, corruption and compromise.

Rapid urbanisation of the region follows an increase in energy demand, unemployment and poverty among the urban poor. Exploration of the climate change-water-energy nexus and its impacts on the livelihoods of populations that depend on energy to earn income to sustain their livelihoods like the informal sector, becomes an important area of research. This exposes the need to further protect and develop sustainable livelihood strategies that create sources of income for the marginalised groups in society like those that trade in the informal sector. The low adaptive capacity of the urban poor to climate change and potentially the climate change and energy security nexus suggests the need to develop strategies that build the resilience of communities in the sector, particularly women. Adaptation measures to the impacts of climate change in cities have focused mainly on building resilience of urban areas from infrastructural damage and disruptions of services due to extreme weather events. Few have looked at building resilience to the impacts that climate change has on the sources of livelihoods of the urban poor. The role of institutions in development and implementation of these strategies that build resilience to the impacts of a climate change induced energy crisis for the urban poor is unquestionable. Stability in energy supply would result in the economic growth of Southern African nations. Climate change threatens this opportunity for growth (Ruppel, 2015).

CHAPTER THREE: METHODOLOGICAL CONSIDERATIONS

3.1. Introduction

This chapter is dedicated to a discussion on the methodology that was employed by this study. Research methodology refers to the researcher's general approach in carrying out the research (Babbie and Mouton, 2010; Leedy and Ormrod, 2010). It is a systematic pathway by which a research problem is addressed (Kothari, 2004; Rajasekar *et al*. 2014). This implies that research methodology is a step-by-step process that outlines the different activities and processes that the researcher engaged in to collect the information used to address the research questions, aims and objectives. For a study of this nature, it is always important to adopt a methodology that is comprehensive, through which the research questions can be answered and research objectives and aims achieved. The chapter aims to present all the data collection tools and methods that were used to carry out the research.

In view of the above definitions, this chapter is made up of three main sections. First will be a discussion on the philosophical position taken by the study. The research design, which describes the research site, the target population and sampling procedure, together with data instrumentation and data analysis, will follow. The last section will be the methodological reflection.

3.2. Philosophical Position/ Research Approach

The research process is known to have four major dimensions which make up the research paradigm: ontology, epistemology, axiology and methodology (Patton, 2002; TerreBlanche and Durrheim, 2007). Paradigms include approaches, theories, models, traditions, body of research, frame of reference and methodologies (Creswell, 2009; Babbie and Mouton, 2010). It is a basic set of beliefs that guide action.

Ontology refers to how we see the world. It is what we believe about nature or reality (Patton, 2002; Kivunja and Kuyini, 2017) . Epistemology refers to our assumptions about the best way to study the world, or how we come to know something that is truth or reality. Axiology looks at ethics and value systems, what we believe is true and what behaviour is right or wrong in research. Methodology is a systematic process we use to study the world, which includes research design, procedures and patterns followed in research (Patton, 2002; Kivunja and Kuyini, 2017). Hence, a person's worldview or perceived aspects of reality are usually concerned with ontological and epistemological aspects while the ethics and values, together with procedures, are concerned with axiology and methodology. The differences in these worldviews and the processes that operate within them influence the researcher's philosophical orientation (Kivunja and Kuyini, 2017).

In this study, the researcher leaned towards the philosophy of pragmatism as a research paradigm. The combination of research approaches led to the adoption of a pragmatic position in this research as it uses both qualitative and quantitative methods of research. Pragmatism is considered suitable for mixed methods research (Creswell and Garrett, 2008; Creswell and Clark, 2010; Tashakkori and Teddlie, 2010). As a worldview, pragmatism arises out of actions, situations and consequences (Patton, 1990; Johnson and Onwuegbuzie, 2004; Onwuegbuzie and Johnson, 2006; Creswell and Clark, 2010; Tashakkori and Teddlie, 2010; Creswell and Clarke, 2011; Morgan, 2014; Kivunja and Kuyini, 2017). It provides a workable solution to multifaceted research problems and offers a practical, 'middle ground' orientation in relation to post positivism and interpretivism (Johnson and Onwuegbuzie, 2004).

Pragmatism research philosophy can integrate more than one research approach and research strategy within the same study. Pragmatists use whatever combination of methods is necessary to find answers to the research questions, hence they favour the use of mixed methods in their research (Creswell and

Clark, 2010; Tashakkori and Teddlie, 2010; Creswell and Clarke, 2011; Kivunja and Kuyini, 2017). The study had research questions that could only be answered using both qualitative and quantitative methods of research. It sought to understand the study population's perceptions of how energy insecurity impacts their livelihoods and get in-depth understanding of their vulnerability to energy insecurity. Therefore, it included open-ended questions in the household survey and interviews with relevant stakeholders. The use of secondary data allowed for a better understanding of the hydro-climatic variability of the study site and allowed the researcher to make inferences on how that potentially has an impact on energy security, particularly for Zimbabwe. The household survey and interviews gave room for the study to explore how this energy insecurity was impacting urban livelihoods in Zimbabwe. This pragmatic approach allowed for the use of a combination of methods to answer the research questions fully.

Instead of focusing on methods, pragmatic researchers emphasise the research problem and use all approaches available to understand that problem (Patton, 1990; Morgan, 2007; 2014; Tashakkori and Teddlie, 2010). Pragmatic researchers therefore grant themselves the freedom to employ a mix of methods, procedures and techniques, whether quantitative or qualitative (Johnson and Onwuegbuzie, 2004; Onwuegbuzie and Johnson, 2006; Tashakkori and Teddlie, 2010). When conducting research, pragmatists believe their research at some stage will take a more subjective approach by interacting with research subjects and at another stage an objective approach that involves noninteraction with research subjects (Tashakkori and Teddlie, 2009).

The same approach was applied in the study as it focused on what approaches would be necessary to address the requirements of the research rather than the methods and techniques required. These became apparent when developing methods to answer the research questions and when data was collected. The first concern was how urban populations were being impacted by energy security in Zimbabwe, given the constant long hours of power outages. This, coupled with the alarming news of low dam levels at Kariba due to droughts, drew attention and interest to the contribution that climate variability had on energy security, especially for countries dependent on hydropower for electricity.

Pragmatism is not committed to any one system of philosophy and reality. During the household survey, data collection also included being imbedded in the experiences of the study subjects. Their experiences and struggles to provide for their families, as female household heads or simply as mothers looking out for their children, was relatable as a parent would do anything to provide for their child. Later, the study was concerned with the quantitative data and the statistical significance of each variable under study, from the household survey, to the hydro-climatic variables from the secondary data acquired. This allowed for both multiple and single realities to be drawn from qualitative and quantitative data and methods of research.

Pragmatism takes on a non-singular reality ontology, recognising that there are different ways of interpreting the world and doing research, and that many realities exist, as each individual has their own unique interpretation of reality (Morgan, 2007; Creswell and Clarke, 2011; Saunders, Lewis and Thornhill, 2012). This was the position adopted by the study during the development of the research questions and data collection. The researcher was able to combine research questions that could only be answered by qualitative data, e.g. perceptions of climate change and its impacts on livelihoods, with those that required quantitative data, e.g. hydro-climatic trends, to address the research questions.

Pragmatic paradigm interests also lie in conducting research that benefits people and finds solutions for the problems people face, hence a value-driven axiology (Patton, 1990; Kivunja and Kuyini, 2017), influenced by the researcher's doubts and beliefs. Researchers use a value-based system to choose the appropriate methods to answer the research questions (Tashakkori and Teddlie, 2009; Creswell and Clarke, 2011). This aimed at finding useful solutions to build adaptive capacity and resilience of urban livelihoods under a changing climate that threatens energy security for Southern Africa. In other words, to explore how else urban dwellers can continue to make a livelihood despite the possible impacts of climate change. Pragmatists agree that research always occurs in social, historical, political and other contexts. This prompted the study to investigate the role of institutions in providing energy security for the people and at the same time, the measures taken to help their populations adapt and build resilience to the situation.

Finally, pragmatism advocates for a relational epistemology (Saunders, Lewis and Thornhill, 2012) which allows the researcher to determine what relationships are worth exploring in the study. The study decided on the target population, the type of information to be collected during interviews and which information to use to effectively answer the research questions. In summary, researchers using the pragmatic approach benefit from a freedom to choose the methods and procedures of research that best meet their needs and purposes.

3.3 Research Design

The research design provides the framework for the processes and procedures involved in achieving the outcomes of the research. It is the blue print for conducting research (Babbie and Mouton, 2007) as it contains a detailed plan of the steps and issues considered when carrying out research. It ensures that the aims of research are achieved. The types of measurement, sampling, data collection and data analysis employed by the study are determined by the research problem (Zikmund *et al.*, 2010).

Given the complexities of the research aim and objections, a solid and purposeful research design was chosen to fully answer the research questions. Research can take a qualitative, quantitative or mixed method approach. Qualitative research involves understanding how groups or individuals ascribe to a social or human problem. Data is collected, usually in the participant's setting, analysed inductively and general themes are drawn, allowing the researcher to make certain interpretations about what the collected data means. The final report drawn out from such an approach is usually very flexible, focused on the individual meaning and expressing the complexity of a particular situation (Creswell, 2008; Babbie and Mouton, 2010; Creswell, 2013; 2014). Quantitative research tests objective theories by exploring the relationships among variables. These variables are measurable, comprising of numbered data that can be analysed using statistical methods. Theories are tested deductively, controlling against bias; alternative explanations are made and methods used in the research can be easily replicated (Creswell, 2008; Babbie and Mouton, 2010; Creswell, 2013; 2014).

The mixed methods approach involves using both quantitative and qualitative approaches to carry out research. This is mainly done to provide a complete and comprehensive understanding of the research problem. According to Johnson and Onwuegbuzie (2004), mixed methods research is formally defined as an approach that combines quantitative and qualitative research techniques, methods, approaches, concepts or language in a single study. This approach is complimentary to both qualitative and quantitative information, thereby increasing the scope and range of research to address the research aims and objectives. It enhances triangulation, considers outsider and insider perspectives, allows for a better understanding of the relationships between variables, and places appropriate emphasis at different stages of research (Johnson and Onwuegbuzie, 2004; Creswell and Clark, 2010; Creswell, 2014). This view is shared by Tashakkori and Teddlie (2009) who acknowledge that combining questionnaires and interviews in a single study increases the breadth and depth of a study. With that in mind, a mixed methods research design was chosen for this research to address the research problem. A mixed method research approach involving hydroclimatic and hydropower data, surveys and interviews was chosen to gain some insight into the experiences of participants and relevant stakeholders to arrive at a conclusion on the role of institutions.

3.3.1 Description of study site

The study comprised of two main study sites. The first study site was in the Kariba sub-basin of the Zambezi River Basin (ZRB). The second was located in Harare, the capital city of Zimbabwe. The Kariba sub-basin lies in the ZRB, which is the biggest basin in southern Africa and the fourth largest on the African continent after the Congo, Nile and Niger river basins as shown in Figure 3.1. It covers a drainage area of under 1.4 million square kilometres, between 8-20° S latitude and 16.5 – 36° E longitude. It stretches across eight countries: of Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia and Zimbabwe (Macdonald, 2007; Tumbare, 2010; ZAMCOM, 2015).

The Zambezi River flows through the ZRB from the Kalene Hills in the north-western mountains of Zambia, more than 1450m above sea level. It flows eastwards through the eight countries listed above into the Zambezi delta, to the Indian Ocean (Tumbare, 2010; World Bank, 2010; ZAMCOM, 2015). The river has tributaries on either banks, Luena, Luanguinga, Lungué-Bungo and Cuando in Angola,; Kafue, Kapombo and Luangwa in Zambia; Chobe in Botswana, Shire in Malawi and Manyame, Sanyati and Gwayi/Shangani in Zimbabwe (ZAMCOM, 2015).

Kariba Dam between Zambia and Zimbabwe, Cahora Bassa Dam in Mozambique along the Zambezi River for hydropower generation, together with the Kafue and Itezhi–Tezhi Dams in Zambia along the Kafue River, make up the four major dams in the basin (World Bank, 2010; ZAMCOM, 2015). Temperature, rainfall, and evapotranspiration affect Zambezi river runoff, whose catchment is characterised by low runoff efficiency and low drainage. A small change in annual precipitation or annual potential evaporation can have a large impact on annual river flows. The relatively high aridity of the basin suggests high sensitivity of runoff to climate change (Cai and Cowan, 2008).

The Kariba sub-basin is one of 13 sub-basins on the ZRB and spans between Zimbabwe and Zambia. The bulk of the sub-basin is located in Zimbabwe, with

Kariba and Victoria Falls being the main towns on the Zimbabwean side of the basin. These towns are home to the Victoria Falls which is a world heritage site and the massive Kariba Dam, which is the largest reservoir in the ZRB, forming Lake Kariba. The Kariba sub-basin is in the middle region of the ZRB, covering 172,527 km^2 from Victoria Falls, through the Batoka Gorge, Devil's Gorge to Kariba Gorge (Beilfuss, 2012). The Zambezi River flows through these gorges. Between Devil's Gorge and Kariba Gorge, it flows through the Gwebi Rift Valley which receives runoff from Gwayi and Sanyati Rivers, whose drainage is from the catchment in the western and northern regions of Zimbabwe (Beilfuss, 2012; ZAMCOM, 2015). It is at this point that the massive Kariba Reservoir inundates the Gwembe Rift Valley floor to create the largest artificial reservoir by volume in the world. It has a storage capacity of 64 800 cm^3, surface area of 5577km and extends over a distance of 280km downstream to Kariba Dam (Beilfuss, 2012).

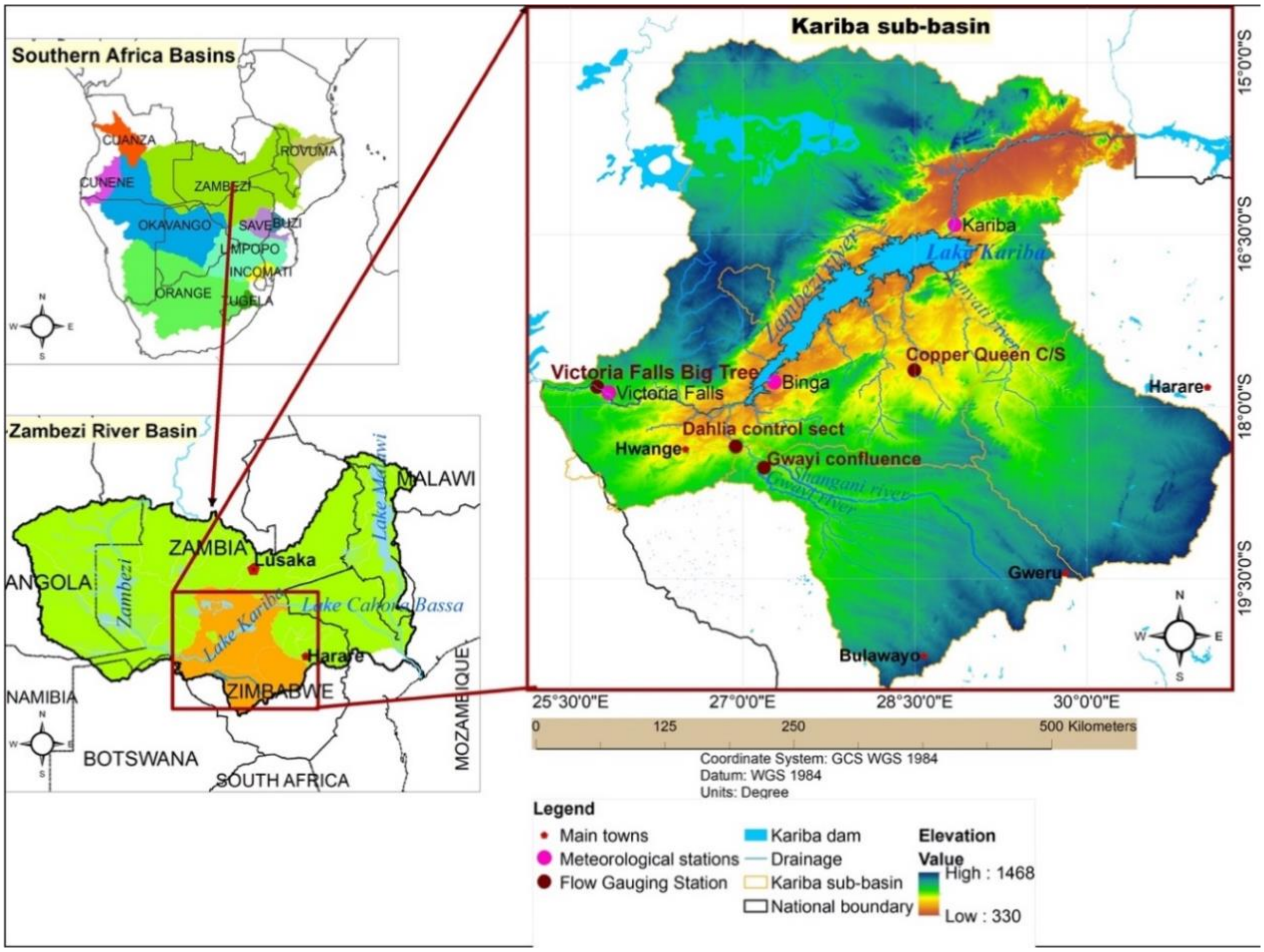

Figure 3.1 The Kariba sub-basin of the Zambezi River Basin with the hydroclimatic stations
Source: Memory Reid

The Kariba sub-basin is the driest in the ZRB and receives the lowest mean annual precipitation (MAP) of 700mm in the Zambezi Basin (World Bank, 2010; Beilfuss, 2012). Runoff and river discharges in the sub-basin are seasonal responding to rainfall events (Davies, 1986; World Bank, 2010; Beilfuss, 2012). About 50% of the Zambezi's total catchment runoff is controlled by the Kariba Dam as its construction has altered the flow regime of the Zambezi River. It has the capacity for 1.4 times the Zambezi mean annual runoff volume, with a constant turbine outflow of 1800-1900 m^3/s (Beilfuss, 2012; Muchuru *et al.*, 2014). Muchuru *et al.* (2014) found rainfall to be the main driver of inflows into the Kariba catchment. Downstream flows are high when the reservoir is at full capacity or close to capacity due to high inflows.

Kariba Dam is a double curvature concrete arch dam with a 627m crest. It was built between 1955 and 1959 in the Kariba Gorge in the ZRB between Zimbabwe and Zambia. It has a storage capacity of about 180 km^3, extends over a length of about 300 km and has a surface area of over 5500 km^2 at full capacity (Tumbare, 2010; Kunz, 2011). Its main purpose is to generate hydropower electricity for Zimbabwe and Zambia, with the water stored also used for the agricultural and recreational sectors of the economy (Mhlanga and Nyikahadzoi, 2017). The two hydropower plants on each side of the dam (North Bank Zambia, South Bank Zimbabwe) in each of the two countries, generate 30% of the hydropower capacity of the Zambezi River (World Bank, 2010). The operation and maintenance of Kariba Dam complex, development of new dams on the Zambezi River and monitoring and analysis of hydrological and environmental issues along the Zambezi River and Lake Kariba is managed by the ZRA under the ZRA Act of 1987 of Zambia and Zimbabwe (Tumbare, 2008; ZRA, 2017). The ZRB's power generation is greatly threatened by drought, which tends to reduce surface runoff and consequently storage volumes in reservoirs, which results in reduced inflows (Yamba *et al.*, 2011) and Kariba Dam is no exception.

Monthly long-term hydrological time series data on river flow was obtained from ZINWA from four gauging stations on four different rivers located in the Kariba sub-basin. The first gauging station was station number ZGP25 in zone A21 located at Victoria Falls Big Tree on the Zambezi River, latitude 17,92 degrees south, longitude 25,83 degrees east. Second was station number A36 in zone AG1 at Dahlia Control Section on Gwayi River, latitude 18,60 degrees south, longitude 27,17 degrees east. Third was station number A36 in zone A51 at the Gwaai Confluence on Shangani River, latitude 18,50 degrees south, longitude 27, 22 degrees east. Last was station number C59 in zone C5 at Copper Queen C/S on Sanyati River, latitude 17,50 south, longitude 29,40 east. The Shangani and Sanyati Rivers are the main tributaries of the Zambezi River from the northern and western regions of Zimbabwe.

Long term monthly time series data on temperature and precipitation was obtained from the Meteorological Services Department (MSD) in Zimbabwe. The data was from three stations, also located in the Kariba sub-basin, which were Kariba Airport, Binga Station and Victoria Falls Airport. The percentage of electricity generated from hydroelectricity sources as a percentage of the total electricity generated from Zimbabwe was sourced from the World Bank website on global energy distribution from different sources. The data represents, to a large extent, long term time series data on electricity generated from the Kariba complex on the Zimbabwe side. This is the case as most of the hydropower generated and distributed on the national grid in Zimbabwe is from the Kariba Hydropower station at 1050MW installed capacity, with small hydropower contributing to about 25MW according to the Ministry of Energy, Power and Development. This data allows for a decent analysis on the trends of hydropower generated in Zimbabwe.

The second study site was used to examine the impacts of the climate change-water-energy nexus above and how it impacts urban livelihoods. A household survey of home-based informal trades was conducted in the residential areas of Harare in Harare Urban district. Harare is the capital city of Zimbabwe. It began as a settlement in 1890 and was proclaimed a city in 1935. Harare is in the north eastern region of Zimbabwe, on a plateau with an elevation of 1500m above sea level (City of Harare, n.d.). Its climate falls into the subtropical highland category. The greater Harare area has a coverage of 872 km^2 and a population of 2.1million (ZIMSTATS, n.d.). The first municipal houses were occupied in Mabvuku in 1952, Mufakose in 1959, Dzivarasekwa and Tafara in 1961 and Marimba – high income, also in 1961 (City of Harare, n.d.).

The suburbs of Warren Park, Kuwadzana, Kambuzuma, Tynwald, Westlea, Parktown, Borrowdale, Mount Pleasant and Marlborough were selected for the study as represented in Figure 3.2. The areas were chosen after looking at their population densities, land or stand size and drawing assumptions about their income levels based on their geospatial location. In Harare, the northern and north eastern suburbs are home to the more affluent population of the city, including the minority white population. They are constituted of well-kept gardens, pools, tennis courts and high tree canopies. Infrastructure is in an acceptable state, with well-placed shopping centres and group A schools. The East has well-kept compact homes which are somewhat a middle ground between the affluent homes of the north east and the roughness of the city centre. Several homes in this area have been turned into offices because of their proximity to the city centre. The residential areas of Belvedere, Avondale, Mandara, Marlborough, Eastlea and Borrowdale fit this description of the north and north eastern suburbs and fall within the Low Density Residential Areas (LDRAs).

The south and south west have a mixture of Medium Density Residential Areas (MDRAs) and High Density Residential Areas (HDRAs), where houses are generally smaller and more tightly packed together. These areas were initially set up by the colonial government from the 1930s onwards. The working class and majority black population reside in these areas. The more affluent residents have bigger properties in the suburbs of Hatfield, Southerton, Tynwald and Prospect which are MDRAs.

Rates of poverty are higher in HDRAs with high rates of unemployment and poor infrastructure. Most households face a daily struggle with poverty, particularly due to the high unemployment rate, hence Warren Park, Kuwadzana, Glen View, Dzivarasekwa and Glen Norah fall into this group. Infrastructure like roads and service delivery is not in an acceptable state, with uncollected refuse and, in worse situations, blocked sewer pipes with sewage running along the streets. HDRAs and MDRAs have large numbers of people participating in the informal sector to earn an income to sustain their livelihoods compared to LDRAs. However, there are challenges in zonation and residential area population as a lot of residential areas are a complex mix of household income levels for residents. For the purposes of this study, assumptions will be made that HDRAs and MDRAs in the south and south west of Harare are where the poorer, low-income urban population resides and the LDRAs of the north and north east are where high-income urban populations reside.

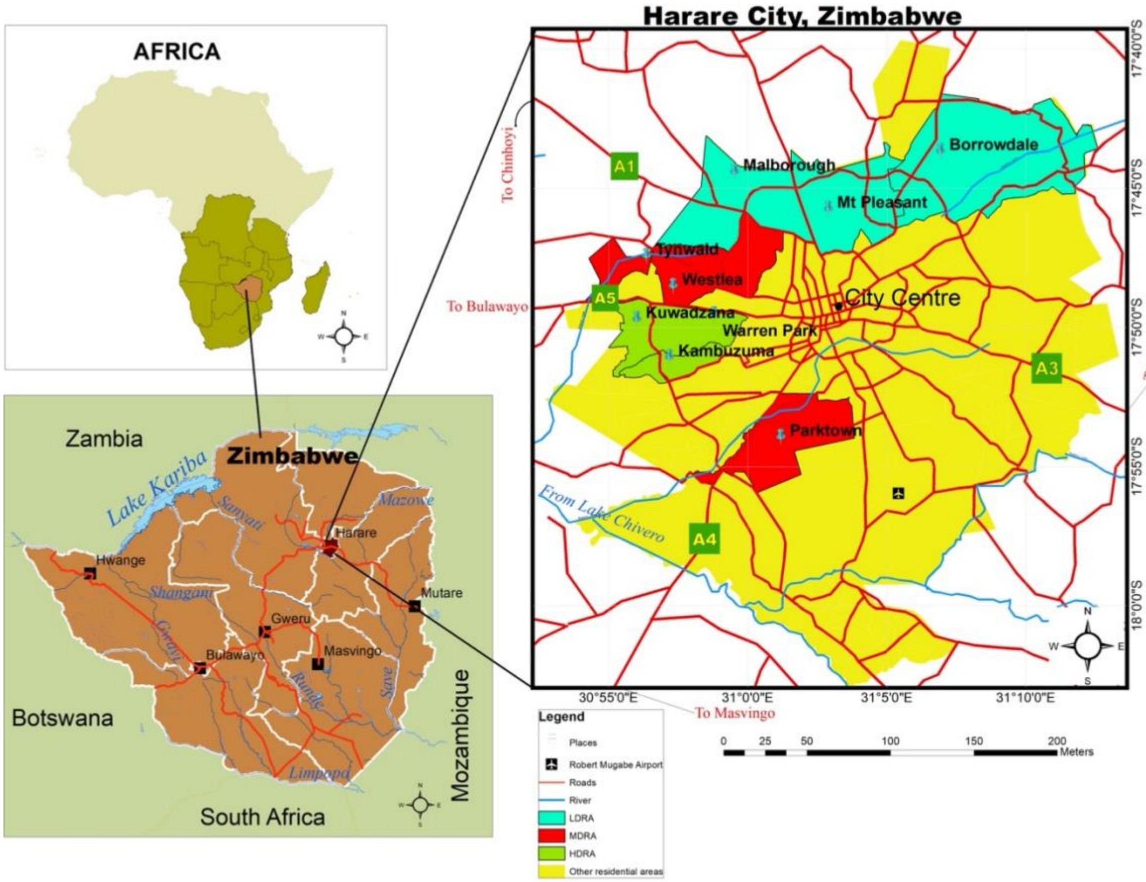

Figure 3.2. Map of Harare and residential study sites
Source: Memory Reid

3.3.2 Target population and sampling procedure

a) Study population

The informal economy comprises a heterogeneous set of economic activities with varying employment statuses (Chen and Sinha, 2016; ILO, 2017). The study targeted the informal sector as defined by the 17th ICLS, which broadened the informal sector to include informal employment. According to the ILO (2003), informal employment refers to all employment arrangements that do not provide individuals with legal or social protection through their work, thereby leaving them more exposed to economic risk than others, whether or not the economic units they work for or operate in are formal enterprises, informal enterprises or households. Studies from the 2014 Labour Force Survey (LFS) in Zimbabwe showed that more women than men were employed in the informal sector, with the largest percentage of informal sector employees operating in their own homes. Hence, the first target population for this study was women in the informal sector who are home-based. The study targeted electricity dependent informal activities performed by women in the informal economy. These businesses relied on availability of electricity to successfully run their businesses. These activities ranged from food services (catering, baking, food processing, refrigeration, etc), tailoring and grinding (mealie-meal, peanut butter) to hairdressing, printing, and packaging.

In addition to the household survey of women in the informal sector, the study engaged with specialised actors from key institutions and relevant stakeholders that could provide information and give in-depth context on the two aims of the research. It was purposefully decided to work with people specialised in areas and sectors related to climate change, water resource management, energy security and urban informal livelihoods. Semi-structured interviews were carried out with all these key stakeholders. The MSD was one such institution. It further provided secondary data on climate variables for the Kariba sub-basin. ZINWA also provided secondary data on the hydrological variables of the Kariba sub-basin. Other relevant information was provided by the ZRA, ZESA, the Ministry of Energy and Power Development, the then ministries of Environment, Water and Climate and that of Industry and Commerce, which housed the Medium and Small Enterprises Department. In the then ministry of Environment, Water and Climate, the departments of Climate and Hydrology were targeted.

The ministries of Lands, Agriculture, Water, Climate and Rural Resettlement; Environment, Tourism and Hospitality Industry; Women Affairs, Community, Small and Medium Enterprise Development now house some of the departments that covered the then ministries of Environment, Water and Climate and that of Industry and Commerce, which housed the Medium and Small Enterprises Department. This change occurred after the July 2018 Zimbabwe elections. Data had been collected between April and May 2018. Additional information on hydropower generated in Zimbabwe as a percentage of total energy in Zimbabwe was sourced from the World Bank data on Global Energy Statistics.

b) Sample size and sampling technique

The population of women in the informal sector of Zimbabwe is 450 816, according to the LFS (2014). The LFS concluded that Harare Province had 16.7 percent of female informal workers, giving a total number of 75 286. From 75 286, we can estimate the number of women in the informal sector of Urban Harare district, which is our study area. However, there are no statistics on the women in home-based informal work, making it difficult to calculate a sample size to represent the women in home-based informal work. They are normally self-employed or unpaid home-based workers (Chen, 2001). This is usually a neglected aspect of the contribution of women to the informal sector as home-based work seldom gets recorded (Hassan and Azman, 2014). They are usually unaccounted for in labour force surveys or national censuses. They are the undocumented missing labour force (Chen, 2001).

However, given the scenario above, where the study could not work out the actual population of home-based women in the informal sector. The study did not work with a sample size, but randomly selected the first participant in the study and used a combination of convenience sampling and the snowballing technique or referral method to get the next participant.

Stratified random sampling was used to select the participants of the household survey. The target population was divided into mutually exclusive, homogeneous segments (strata). Three strata were used in the study which was based on the population densities of suburbs in Harare, namely HDRAs, MDRAs and LDRAs. In stratified sampling, the number of participants sampled from each stratum is calculated proportionally to the total population (Kothari, 2004). Advantages of stratified sampling include ease and possibility to draw inferences within each stratum and to make comparisons across stratum. In addition, data collection costs may be reduced if the population is divided into homogeneous geographical areas, which facilitates data collection. Stratified sampling allows for analysis to be done within each stratum and makes it possible for different research methods to be applied in each of the different strata.

However, there were challenges in zonation and residential area populations as a lot of residential areas are a complex mix of household income levels for residences. Given the difficulties in getting actual population sizes and densities due to zoning that overlaps between districts and wards, assumptions were made that high-density area populations are higher compared to MDRAs, and MDRAs populations are higher than LDRAs. Furthermore, locating respondents from LDRAs was difficult compared to MDRAs and HDRAs as houses in LDRAs are sparsely distributed compared to MDRAs and HDRAs. The same applied to MDRAs compared to HDRAs. Based on this the researcher sampled more participants from HDRAs, followed by MDRAs, with the least from LDRAs. Therefore, using a ratio of 3:2:1 for HDRAs, MDRAs and LDRAs respectively, the researcher sampled 50% of respondents from HDRAs, 33% from MDRAs and 17% from LDRAs. In total, the researcher had 150 respondents: 75, 50 and 25 from each stratum of HDRAs, MDRAs and LDRAs respectively.

Participants were women in home-based informal employment that is energy dependent. As previously mentioned, a combination of snowballing and convenience sampling methods were used to identify participants. Snowball sampling was used as members of the desired sample ply their trades in their homes and are difficult to identify. Hence, after the first respondent was located, they were asked to locate similar respondents until the sample size per stratum was achieved. Convenience sampling was used for the same reasons stated above, as it was difficult to locate informal traders that are home-based.

Therefore, interviewing available and willing participants until data saturation was ideal, until some sort of a pattern or theme was observed.

Sampling of specialised respondents in the areas and sectors related to climate change, water resources management, energy security and urban informal livelihoods was also carried out. This involved purposefully choosing areas and conducting interviews based on the potential information they would provide and how it would help answer the research questions. At each institution, the first port of call was the receptionist in attendance. The receptionist asked for a letter requesting for an interview, including the participant information sheet. The researcher was then referred to the Human Resources Officer, who in turn, referred the researcher to the relevant specialised respondent to be interviewed. If the information was not enough, the researcher was referred to a different person in a different department. In total, seven specialised respondents made up the sample.

3.3.3 Data collection and instrumentation

Data collection is the process by which a researcher collects the information required to answer the research questions. Data collection methods are used to achieve set objectives in research (Creswell, 2014). To shed light on the impacts of the climate change-water-energy nexus on urban livelihoods, primary and secondary data was collected. The research employed both quantitative and qualitative methods. Several data collection tools were implemented in data collection, which fell in line with the mixed method approach of the study discussed below.

a) *Household survey questionnaires*

The study carried out a household survey by conducting structured interviews using a questionnaire (see Appendix E). A survey allows for a quantitative or numeric description of trends, attitudes or opinions of a population (Creswell, 2004). At the same time, questionnaires usually include a set of standardised questions that explore a specific topic and collect information about demographics, opinions, attitudes or behaviours. Given that the survey was cross-sectional, data was collected at one point in time. Quantitative and qualitative data was collected using open and close-ended questions to get information from women in the informal sector. The questionnaire was developed using the nine steps to develop questionnaires by Churchill and Iacobucci (2002). These steps are illustrated in figure 3.3 below.

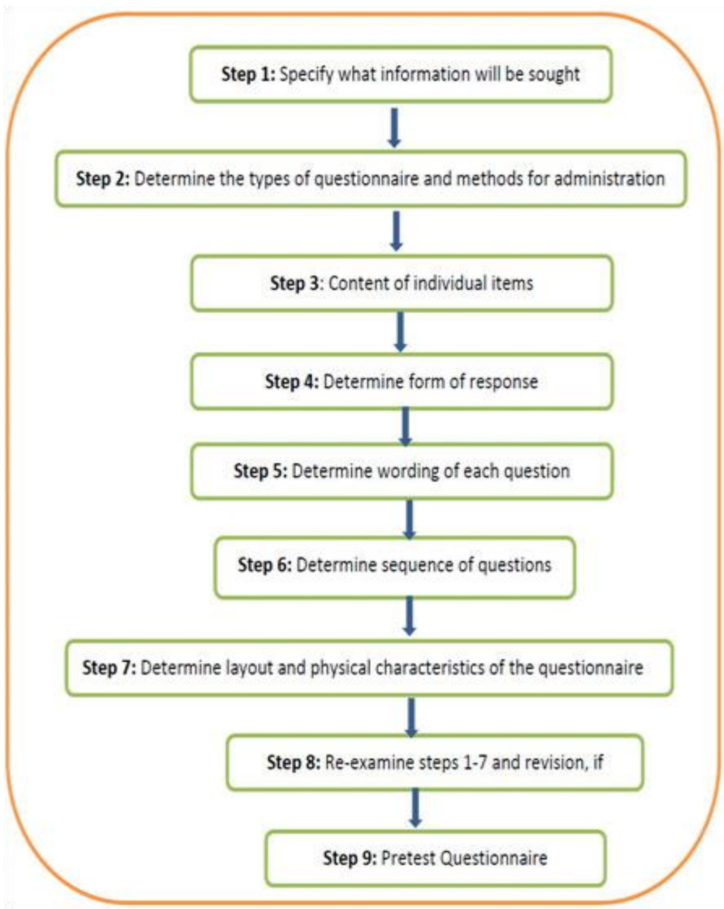

Figure 3.3 Questionnaire development steps.
Source: Source: Churchill and Iacobucci (2002, p. 315)

The questionnaire used in the study had two sections, Sections A and B. A participant information sheet, together with a consent form, was issued and signed before respondents could take part in the survey (see Appendices D and A respectively). Section A sought the background information of the respondents.

It contained socio-economic demographics of the households under study. This included household structure, income and finances, property ownership and assets owned. Section B gathered information on the home-based enterprise. It requested information on structure, goods and services offered, employment structure and conditions of enterprise, energy use, business operation and the role of institutions.

The collection of both qualitative and quantitative data helped get a broad extensive profile of women in the informal sector, including their biographical data, socio-economic status, livelihood strategies, income generation, assets and savings. The questionnaire also provided information on how availability of electricity affects their trades and livelihoods. Additionally, it collected information on the strategies employed by women in home-based informal work when electricity is unavailable. Hence, the questionnaire collected information on the background and characteristics of their business or trades and how they are impacted by energy insecurity. The distribution or respondents per residential area is presented in Table 3.1.

Table 3.1 Summary of number of respondents per residential area.

	Residential Area	**No of Respondents**
High Density Residential Areas (HDRAs)	Warren Park	25
	Kambuzuma	22
	Kuwadzana	28
Medium Density Residential Areas (MDRAs)	Tynwald	17
	Parktown	21
	Westlea	12
Low Density Residential Areas (LDRAs)	Borrowdale	6
	Marlborough	10
	Mount Pleasant	9

Source: Field Survey (2018)

b) ***Key informant interviews***

Semi-structured interviews were used to get an in-depth understanding of the impacts of the climate change-water-energy nexus on urban livelihoods. This qualitative research method involves conducting one-on-one interviews with respondents to explore their individual perspectives on certain issues. Interviews are useful as the researcher has control over the line of questioning and participants can provide background and historical information. Audio recording was used during the one-on-one interviews, which allowed the researcher to capture all the issues addressed and information provided by the key informants in the study. A list of the interview participants is given in Table 3.2.

Table 3.2 Interviews carried out with key informants.

Institution	Person Interview	Date
Meteorological Service Department (MSD)	Deputy Director	09/05/2018
Ministry of Energy, Power and Development	Senior Energy Development Officer	17/05/2018
Ministry of Environment, Water and Climate (Climate Change Management Department)	Climate Change Scientist	08/05/2018
Ministry of Environment, Water and Climate (Hydrology Department)	Chief Hydrologist	08/05/2018
Zambezi River Authority (ZRA)	Manager of Finance and Administration	09/05/2018
Zimbabwe Electricity Supply Authority (ZESA)	Group PR Manager, Stakeholder Relations Manager	14/05/2018
Department of Small and Medium Enterprises and Cooperative Development	Director	09/05/2018
Zimbabwe National Water Authority (ZINWA)	Senior Hydrologist	11/05/2018

Source: Field Interviews (2018)

Information from key informants like government departments and institutions was collected using these semi-structured interviews (see Appendices F to L). Before each interview, a participant information sheet (see Appendices B and C), together with a consent form (see Appendix A), were issued and signed by the participant. The interviews were recorded to capture all the issues discussed. This allowed the researcher to explore the role of institutions and government in climate change debate and its impacts on livelihoods. Data collected from in-depth interviews was qualitative. Key specialised informants from the MSD and ZINWA also provided secondary quantitative data on climatic and hydrological variables such as river runoff of several rivers from gauging stations in the Kariba sub-basin, as well as temperature and precipitation from three stations in the Kariba sub-basin.

c) *Hydroelectricity data*

The World Bank website on global electricity distribution from different energy sources provided long-term hydroelectric data for Zimbabwe. This data was a percentage of electricity generated from hydropower from the total electricity generated in Zimbabwe. The data represents, to a large extent, long-term time series data on electricity generated from the Kariba complex on the Zimbabwe side. This is most likely the case as most of the hydropower generated and distributed on the national grid in Zimbabwe is from the Kariba Hydropower Station. This data allows for a decent analysis of the trends of hydropower generated in Zimbabwe. This information helped shed light on the climate change-water-energy nexus in the Kariba sub-basin. The quantitative secondary data collected above allowed the researcher to explore the climate change-water-energy nexus and the relationships between hydrological and climatic variables in the sub-basin.

3.3.4 Data analysis

The relationships, patterns, trends, attitudes and perceptions of respondents in research can be examined through data analysis. Quantitative analysis is objective as it involves critical analysis and interpretation of figures according to mathematical computations. On the other hand, qualitative analysis is deemed subjective as it is dependent on the opinions and inferences of participants (Kothari, 2004; Creswell, 2008; Babbie and Mouton, 2010). Given that the study took on a mixed method approach, data was analysed quantitatively and qualitatively. The hydroclimatic and hydropower output elements of the research had quantitative data and was analysed using R studio statistical package, MAKESENS10 and Microsoft Excel Data Analysis. The livelihoods section had quantitative and qualitative data and was analysed using IBM SPSS Statistics software, together with Microsoft Excel.

Data analysis and interpretation were conducted using both descriptive and inferential statistics. The descriptive statistics were used to describe the distribution of the data using mean, minimum, maximum and standard deviations for the numerical variables, while frequencies and graphs were used to report categorical variables. Inferential statistics were used to make judgments based on the samples collected from the target population. Hypothesis testing was used to make judgements on results from trend analysis, linear regression and chi-square tests that gave patterns and relationships between and among variables.

a) Hydroclimatic and electricity data

The long-term hydroclimatic time-series data consisted of three variables: temperature, precipitation and river runoff. Trend detection was performed on these variables. Trend analysis of time series hydroclimatic data involves establishing the existence of a significant trend, whether the trend is increasing or decreasing and the magnitude of the trend (Jain and Kumar, 2012). Trend analysis of these variables was carried out using the Mann-Kendall (MK) test as it had been adopted by others to analyse hydroclimatic data (Birsan *et al.*, 2005; Pal *et al.*, 2017; Asfaw *et al.*, 2018). Mann-Kendall is a non-parametric method, commonly used for detection of statistically significant trends in variables like rainfall, temperature and stream flow (Mann, 1945; Kendall, 1957; Yue *et.al.*, 2002). The MK test was chosen as it does not require datasets to follow a normal distribution, can tolerate outlier data and can analyse data with missing values, which occurs quite often with hydroclimatic time series data (Hamed and Rao, 1998; Birsan *et al.*, 2005). If the total data in the time series is indicated by n, then the Mann-Kendall statistic S can be computed as follows.

Statistic S for trend is:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \text{sgn}(x_j - x_i) \quad 3.1$$

Here x_i x_j are the sequential data values, n is length of data set and sgn is the sign function.

$$Sgn(x_j - x_i) = \begin{cases} +1, > (x_j - x_i) \\ 0, = (x_j - x_i) \\ -1, < (x_j - x_i) \end{cases} \quad 3.2$$

The Z statistic is as follows:

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{Var\ (S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \dfrac{S+1}{\sqrt{Var\ (S)}} & \text{if } S < 0 \end{cases} \quad 3.3$$

where a positive and negative Z indicates an upward and downward trend for that period, respectively.

Before applying the MK test to all the time series data, it was investigated whether the data was serially correlated. To run the test for serial correlation, the missing data points had to be filled in. Next, the test for serial correlation was done in R statistics that produced autocorrelation (AFC) and partial correlation (PACF) plots. Determining the presence of serial correlation would require visual investigation of the vertical spikes in the ACF and ACF plots produced by R. The spikes would need to fall outside the horizontal blue dotted bands of the ACF and PACF box plots for autocorrelations and partial autocorrelations to be deemed significant. If the data were serially corelated, one would need to use the MK test in conjunction with block bootstrapping to account for the serial correlation present in the hydroclimatic data. Hence, the MK test would be modified. However, the data showed no serial correlation (see Appendix N), so the MK test using R statistics was applied as is.

To estimate the true slope of an existing trend (as change per year), the Sen's nonparametric method was used. The Sen's method for the magnitude of a trend can be used in cases where the trend can be assumed to be linear (Sen, 1968).

The slope T_i between two values of a time series is as follows:

$$T_i = \frac{x_j - x_k}{j - k} \tag{3.4}$$

where X_j and X_k are the data values for j and k times of a period where j>k. The median of these N values of T_i (the slope) represents Sen's estimator of slope. Sen's slope estimator is represented by Q_i

$$Qi = \begin{cases} T_{\frac{N+1}{2}} & N \text{ is odd} \\ \frac{1}{2}\left(T_{\frac{N}{2}} + T_{\frac{N+2}{2}}\right) & N \text{ is even} \end{cases} \tag{3.5}$$

A positive value of Q_i indicates an upward or increasing trend and a negative value of Q_i gives a downward or decreasing trend in the time series.

The magnitude of the trend was analysed using MAKESENS10, which uses an Excel template. However, to run the nonparametric Sen's method for the magnitude of trend, a non-parametric MK test is calculated to produce results for both the MK test and Sen's slope. With the MK test and Sen's method, data can be analysed with missing values and does not have to be normally distributed. When the MK test in MAKESENS10 was run, there was no need to fill in the missing values, as was with the case of the MK test using R.

Trend analysis was carried out on an annual as well as seasonal (wet and dry) basis. Long term trends in temperature and precipitation for stations in Victoria Falls, Binga and Kariba were analysed. They provided climatic trends in the Kariba sub-basin. Long term trends in river runoff for gauging stations on the Zambezi, Shangani, Gwayi, and Sanyati rivers were also analysed. These provided hydrological trends in the Kariba sub-basin. Long term trends of percentage of electricity generated from hydropower from the total electricity generated in Zimbabwe were also analysed. This gave an indication of the patterns of hydropower output generated in Zimbabwe. Kariba Hydropower Station is the only big hydropower plant in Zimbabwe. That being the case, the long-term trends of percentage of electricity generated from hydropower from the total electricity generated in Zimbabwe was then used as a proxy for hydropower output at Kariba Hydropower Station.

In running the MK test on all the variables, the null and alternative hypotheses are as follows: H_0 = no trend, H_1 = monotonic trend. If the p value is less than the significance level α (alpha) = 0.05, H_0 is rejected. Rejecting H_0 indicates that there is a trend in the time series, while accepting H_0 indicates no trend was detected. On rejecting the null hypothesis, the result is said to be statistically significant. The Sen's slope, which is the magnitude of change was measured, with output Q which estimated the slope, together with a (MK) p value which was represented by * or + for different confidence intervals. After running the trend tests in R and MAKESENSE10, results are presented both numerically and visually. Graphs serve as a visual representation of the trends and their direction, which is always produced in tables. In the MK test, parameters like Kendall's tau, S statistic and the Z statistic, including Sen’s Q, were considered to identify the increasing or decreasing trend in the time series of climatic parameters. The significant p values for MK tests ran using R statistical software were shaded in different colour codes, while the MAKESENSE output had different signs to represent the various confidence intervals as indicated in Table 3.3.

Table 3.3 Explanation of significant trends at varying confidence levels

R Statistics (R)Output	MAKESENSE10 (MS)Output		
	***	if trend at α = 0.001 of significance	
	**	if trend at α = 0.01 of significance	
	*	if trend at α = 0.05 of significance	
	+	if trend at α = 0.1 of significance	

Source: MAKESENS10

Next, the relationships among the hydrological, meteorological and hydroelectricity generated were analysed using simple linear and multiple linear regression. Simple or multiple linear regression analysis is used as a tool for predicting a quantitative response variable. Multiple linear regression analyses are a set of statistical techniques used to assess the relationship between one quantitative dependent (response) variable and several independent (predictor) variables (Tabachnick and Fidell, 1996). The objective of a regression model is to predict a single dependent variable from the knowledge of one or more predictor variables. When a single predictor variable is used to predict the response variable, it is referred to as simple linear regression. Simple linear regression analysis is a statistical technique used to analyse the relationship between a single dependent variable and one independent variable (Hair *et al.*, 2010). In practice, there is often more than one predictor variable. Instead of fitting a separate simple linear regression model for each predictor, a better approach is to extend the simple linear regression model to directly accommodate multiple predictors. Thus, a multiple linear regression model uses two or more variables to predict the response variable (Tabachnick and Fidell, 2012). A simple linear regression model is represented as:

$$y_i = \beta_0 + \beta_1 X_i + \varepsilon_i \quad i = 1,.....n \tag{3.6}$$

β_0 is the intercept, β_1 is the slope, X_i is the predictor variable and ε_i represents the error term of the random response variable y_i. The X_i is assumed to be fixed and ε_i are independent random variables with $E(\varepsilon_i) = 0$ and $\text{var}(\varepsilon_i) = \sigma^2$.

The multiple linear regression model is given by:

$$y_i = \beta_0 + \sum_{k=1}^{p} \beta_k X_k + \varepsilon_i \tag{3.7}$$

where p represents the number of predictor variables. The parameters

$\beta_0, \beta_1, ... \beta_p$ need to be estimated.

The correlation coefficient, R squared, gave a measure of goodness-of-fit of the regression model and ranged between 0 and 1. The p-value gave an indication to whether a linear relationship existed for the variables in the model where the Ho: $\beta j = 0$ against Ha: $\beta j \neq 0$. A p-value > 0.05 was therefore statistically insignificant in predicting the dependent variable, whereas p-value < 0.05 was statistically significant.

With the above being the case, the long term annual and seasonal variations in hydrological variable runoff (R), climatic variables precipitation (P), temperature (T) and hydroelectricity generated (HE) were analysed on the Zambezi River, using simple and multiple regression. Data captured at Victoria Falls Big tree gauging station for R and Victoria Falls Airport for T and P, together with HE generated in Zimbabwe, the bulk of which comes from Kariba Hydropower Station at Kariba Dam, was used. This was the only location where all data on climatic, hydrological and hydroelectric patterns was present. Hence, it was the best place to explore the relationships among the variables. The relationships also have a bearing on energy security for Zimbabwe.

According to Mukheibir (2007), changes in temperature and rainfall have the potential to affect hydropower generation/potential in three major ways: surface water evaporation, reduced or increased runoff and siltation deposits. The researcher investigated how T and P impact R. Potential declining river flows due to climate change may lead to declining hydropower production, which in turn would have an impact on energy security, especially in countries that depend heavily on hydropower as an energy source. So, the relationship between R and HE was also analysed. This helped understand the interaction between climate change and hydrological processes and how that impacts hydropotential.

The next part of the study involved establishing a relationship between the climate change-water-energy nexus and urban livelihoods. This was done by analysing how electricity impacts the livelihoods of the urban poor. IBM SPSS Statistics software, together with Excel, was used to analyse both the qualitative and quantitative data collected from the household survey and in-depth semi-structured interviews from relevant stakeholders. Questionnaire responses were edited, and cross checked for consistency and completion. These responses were classified into categories then coded and entered into an Excel spreadsheet. Responses for each questionnaire were then entered into another excel spreadsheet using the codes created, making it easier to analyse them. Although the questionnaires were individually administered during the household survey, anonymity of the respondents was maintained, hence, each questionnaire was assigned a number in place of the respondent's name.

Excel was used to handle and analyse the data as it has many features that are favourable and compatible with the data collected from the household survey, making it very flexible. Excel is also compatible with a lot of other software used to analyse data and apply statistics to it. In this case, responses that were sorted in Excel, were exported to IBM SPSS without any challenges. Excel also has an add-in for data analysis, making it easy to statistically analyse the collected data. It also integrates well with other Microsoft Office software products, which makes it possible to produce reports and represent data with ease. Descriptive statistics was used to analyse the data on socio-economic demographics and the characteristics of the businesses of the respondents in the household surveys. A comparative analysis was carried out among residential areas and contrasted against different variables. These included socio-economic demographics, energy dependency of business, electricity availability, adaptive strategies employed and impacts on livelihoods.

Data collected from the household survey was primarily presented using descriptive statistics in the form of means, medians and frequencies presented in tables and charts. These helped summarise and allowed conclusions to be drawn about the study population. Interactions were analysed using IBM SPSS Statistics. Contingency tables and Chi squared tests were used to analyse the associations between categorical variables. The chi-square test for independence, also called Pearson's chi-square test, was used to investigate whether two categorical variables had a relationship. H_0 = no association/independence; H_1 = association/dependence (Field, 2013). When there was a relationship, Phi and Cramer's V were used to test the strength of the association. Phi and Cramer's V vary between 0 and 1 without any negative value. Cramer's V is an alternative to Phi in tables bigger than 2×2 tabulation. A value close to 0 signified weak or no association, but a strong relationship exists when the value is bigger than 0.25 (Akoglu, 2018).

b) Key informants' interviews

Qualitative data collected from the in-depth one-on-one interviews was analysed using content analyses. Content analysis is a method used to analyse written, verbal or visual communication in an objective and systematic manner (Haggarty, 1996). It is the analysis of what the collected text discusses, interpreting the underlying meaning of the text (Erlingsson and Brysiewicz, 2013).

The study followed the steps outlined by Graneheim and Lundman (2004) and Erlingsson and Brysiewicz (2013) for content analysis. This involved carefully listening to all the recordings from the informants and transcribing the interviews by writing down the responses provided. The recordings gave the researcher substantial information on the areas of interest. These were then reread to get a better understanding of the information provided in the responses from key informants. Next, the text was divided into meaning units that contained similar aspects from the interviews. These units were then shortened, without losing the core meaning of the content, in a process called condensation. The condensed phrases were then coded. The codes were grouped into categories based on their different relationships. A category answers the question "What?". Abstraction was used, whereby the categories were named using the content characteristic words (Erlingsson and Brysiewicz, 2013). The categories were presented in a table format with the responses to those categories also represented. The method ended here and did not go further into developing themes as the "What?" aspect of the research question had been fulfilled.

3.4 Methodological Reflection

Carrying out academic research in Zimbabwe had its ups and downs. Participants usually questioned the researcher's true identity, whether the intentions of the research were political and if the research would economically benefit them. Participants worried about interacting with journalists and needed reassurance that the research was purely for academic purposes. With that being the case, respondents were generally co-operative. The household survey was the most challenging and tedious part of the research process. It was challenging to find the first respondent in each residential area visited. The first attempt was in Warren Park, where the researcher started with the markets that sell vegetables to get some direction towards potential respondents. The lady with the vegetable stall was quite accommodating and pointed the researcher towards the first female home-based informal business owner who is known for sewing bedding and curtains. At the mention of the referrer, she became more open to engage and allowed the researcher to conduct the interview. A similar pattern occurred in each new residential area.

Establishing first contact in the low-density suburbs was more challenging as there were few people wandering the streets. On a few occasions, assistance was rendered by domestic workers on their way to or from the shops. They provided information about a lady they sourced supplies from, especially those in food production businesses. However, there were no responses at the gates of several referred low-density residents; either no one was home, they could not hear the banging at their gates, or they were simply not interested. A considerable number of respondents had their businesses advertised on their gates, especially in the high-density areas, which made it easier to choose sample.

High-density respondents were more willing to participate in the survey, although there was a common question regarding the incentives on offer for participation. Older participants quickly identified the researcher with their own children and therefore had more time to participate in the survey and gave a lot of useful information. Some of these interactions became very emotional as many of the female respondents broke down while explaining the economic hardships. They explained how they have been reduced to do work they feel is either too tedious or beneath them, just to earn a living. Many made reference to former successful careers and to the retirements they had planned for that never materialised.

The interviews with key stakeholders and institutions went well. Government departments had more protocols to be observed before interviews could be conducted, especially the Ministry of Energy and Power Development. Energy is considered part of national security, hence many boxes had to be ticked before an interview was granted. First, they required a letter requesting an interview and stating its purpose, as well as several documents from the researcher's academic institution. These documents were sent, through human resources, to the director for approval. Only after human resources had approved would the researcher get the opportunity to interview the specialised key informant of that government department. However, response time varied between ministries, from two days to more than a month. Sometimes, the delays came from reception or human resources, who required further explanation or understanding of what the research involved. In hindsight, more lead time is required when dealing with governments departments. Other institutions like ZRA, ZESA and ZINWA, to name a few, were much easier to access and enter. They were able to immediately assign someone to respond to the interview questions. Secondary data from ZINWA was obtained on the same day and more data was emailed when requested.

Across all key informants, interviews were carried out with high-level members of staff, including directors of departments. Respondents who are, or have been, in the academic space before expressed a lot of enthusiasm, making the conversations easier. This ease in conversation played a major role in the securing of secondary hydrological and climatic data from ZINWA and MSD. Instead of making inferences about the hydrological and climatic variability of the Kariba sub-basin from other researchers' work, the researcher was able to measure and draw personal conclusions about the hydroclimatic variability of the region using the acquired data.

The researcher was able to interview most of the targeted key informants and respondents were very generous with their time. The household survey was the most tedious. As with the semi–structured interviews, household survey respondents were very generous with their time. Looking back, a research assistant would have gone a long way in offsetting the load, as a lot of walking and talking was required. Being able to communicate in the local language, Shona, came in handy as it was easy to make small talk before administering the questionnaire. All the respondents were literate, making reviewing the participant information sheet, consent form and questionnaire easy. Further explanations about the research were easily understood.

CHAPTER FOUR: EMPIRICAL EVIDENCE

4.1 Introduction

This chapter presents the empirical evidence of the study, collected between April 2018 and August 2019. The chapter indicates the intentions of the study and examines and presents the results. It is important to have empirical evidence from which to make assumptions and draw conclusions; hence, the findings were structured and categorised around the research questions of the study. Through a process of repetitive reading and writing/reviewing, themes relating to the research questions were drawn out and employed to understand the impacts of a climate change-water-energy nexus on urban livelihoods. The chapter is organised to present findings on; (1) temporal trends over 50 years of climatic, hydrological and hydropower generation in the Kariba sub-basin, (2) the relationships among climatic, hydrological and energy (hydropower) output variables, (3) characteristics of women in informal business, 4) energy insecurity in the informal sector and, (5) the role of institutions in the climate change, water energy and urban livelihoods. The evidence collated from this process is presented in the form of tables, graphs and charts.

4.2 Assessing Inter Annual Climatic, Hydrological and Hydropower Generation Trends in the Kariba Sub-Basin

This section presents results on the hydroclimatic variables and the hydropower electricity generated in the study sites. One of the components this study was interested in was the impact of a climate change-water-energy nexus on urban livelihoods. Historical and current changes in climate, hydrology and hydropower generation in the Kariba sub-basin were explored. The intention was to establish a link between climate, water and energy. It was important to know the changes of these variables over space and time, to draw a conclusion regarding the patterns observed. Furthermore, their relationships and interactions allow for conclusions to be drawn on their correlations. This allows for further analysis into their impacts on urban livelihoods.

4.2.1 Temperature

One of the climatic variables this study was interested in was temperature trends, to assess climate variability and change in the sub-basin. Average annual maximum temperatures (Tmax) in the Kariba sub-basin follow a similar pattern, as temperatures increased and decreased in a similar fashion for the three stations. Temperatures appeared to be highest in Kariba and lowest in Victoria Falls, as illustrated in Figure 4.2.1.

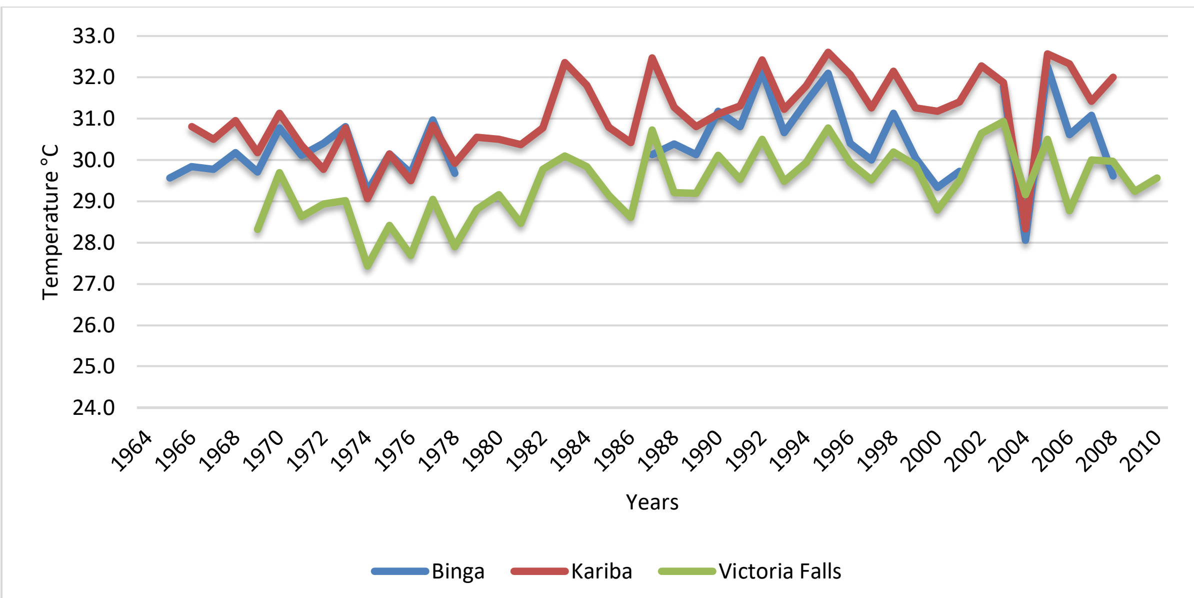

Figure 4.2.1 Long-term average annual maximum temperature patterns over the Kariba sub-basin
Source: Based on data from MSD (2018)

Based on the null hypothesis that there is no trend at 5% significance level, we reject the null hypothesis, as a trend is noticeable for average annual Tmax for all three stations as illustrated in Table 4.2.1. A positive Z and Q indicates an increasing trend which is plotted in Figures 4.2.2, 4.2.3 and 4.2.4. This suggests a temporal increase in annual maximum temperatures in the Kariba sub-basin.

However, the same cannot be said about the seasonal temperatures, which showed an increasing trend, but were not significant at alpha 0.05.

Table 4.2.1 Trend analysis for maximum temperatures in the Kariba sub-basin (1964-2010)

Location	Meteorological Station	Years Recorded	Period	MK (Z)	P-value (MS)	Sen's SE (Q)	P-value (R)	tau
Victoria Falls	Victoria Falls Airport	1969-2010	Annual	3.620	***	0.037	0.00029492	0.389
		68/69-09/10	Wet season	1.040		0.025	0.29816	0.113
		68/69-09/10	Dry Season	0.217		0.004	0.8284	0.024
Kariba	Kariba Airport	1964-2009	Annual	3.996	***	0.039	0.000064492	0.409
		65/66-08/09	Wet season	0.021		0.001	0.97579	-0.004
		65/66-08/09	Dry Season	0.481		0.009	0.63023	0.052
Binga	Binga	1964-2008	Annual	1.839	+	0.022	0.019876	0.245
		64/65-07/08	Wet season	0.046		0.002	0.26183	-0.121
		64/65-07/08	Dry Season	0.263		0.003	0.59097	-0.059

Source: Based on data from MSD (2018)

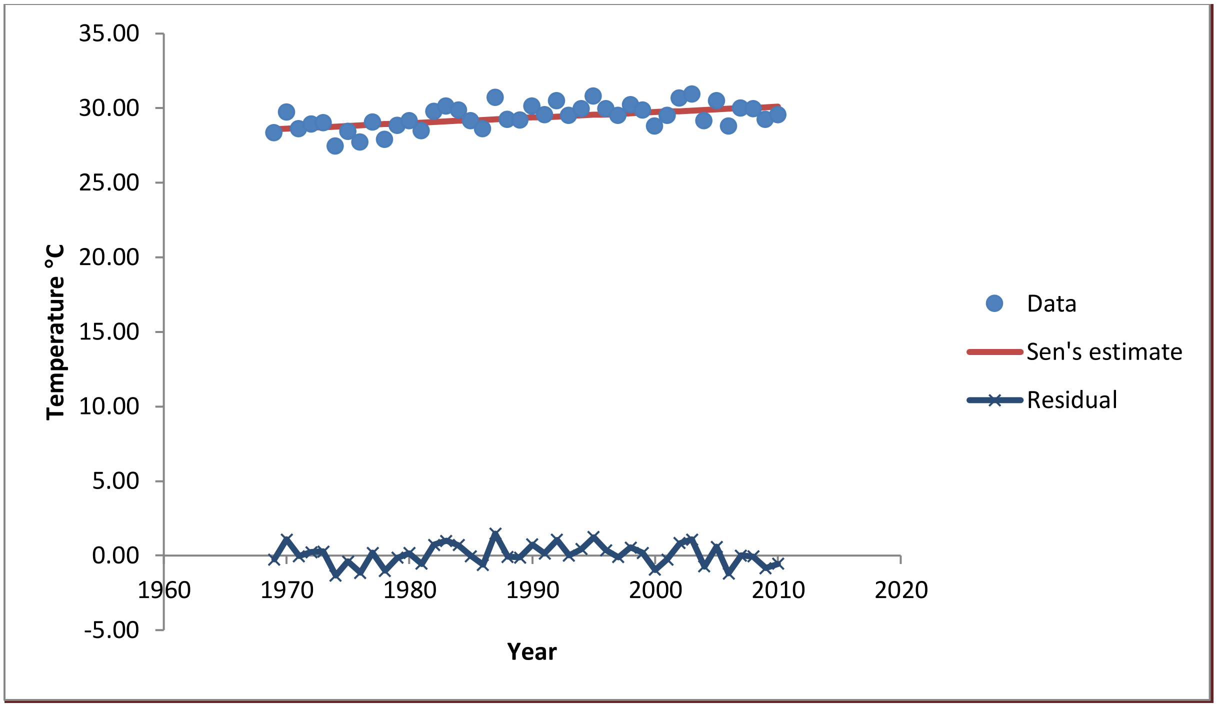

Figure 4.2.2 Trend and Sen’s slope for Victoria Falls annual maximum temperatures (1969-2 010)

Source: Based on data from MSD (2018)

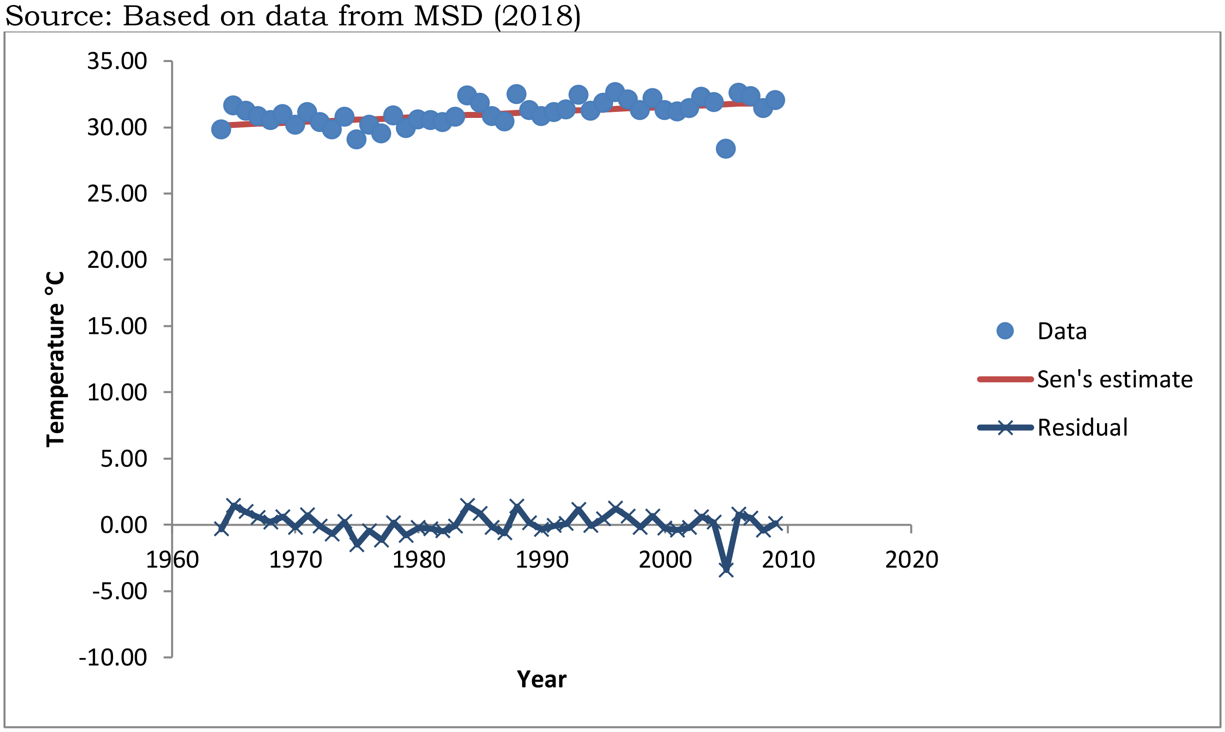

Figure 4.2.3 Trend and Sen’s slope for Kariba annual maximum temperatures (1964-2009)
Source: Based on data from MSD (2018)

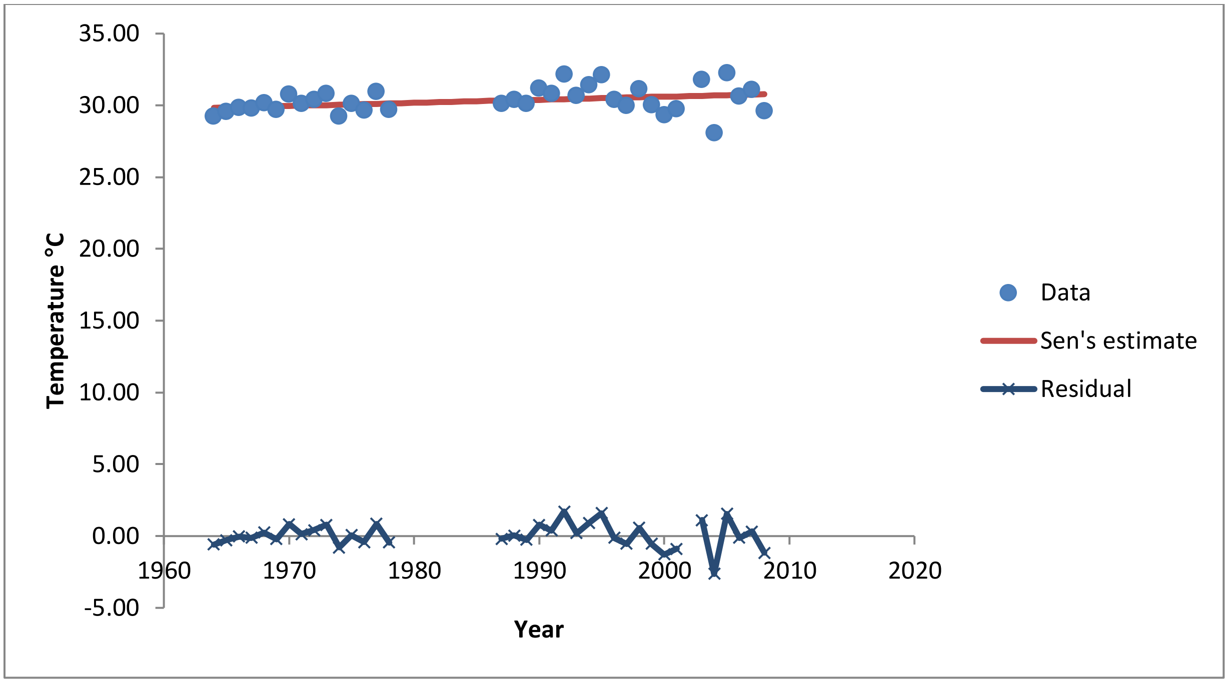

Figure 4.2.4 Trend and Sen's slope for Binga annual maximum temperatures (1964-2008)
Source: Based on data from MSD (2018)

Average annual minimum temperatures in the Kariba sub-basin follow a similar pattern, increasing and decreasing uniformly as shown in Figure 4.2.5. Minimum temperatures were highest in Binga and lowest in Victoria Falls over the years. However, there was a huge drop in temperature in 2004 at all stations. This could have been a recording error, and possibly impacted on the negative trends observed.

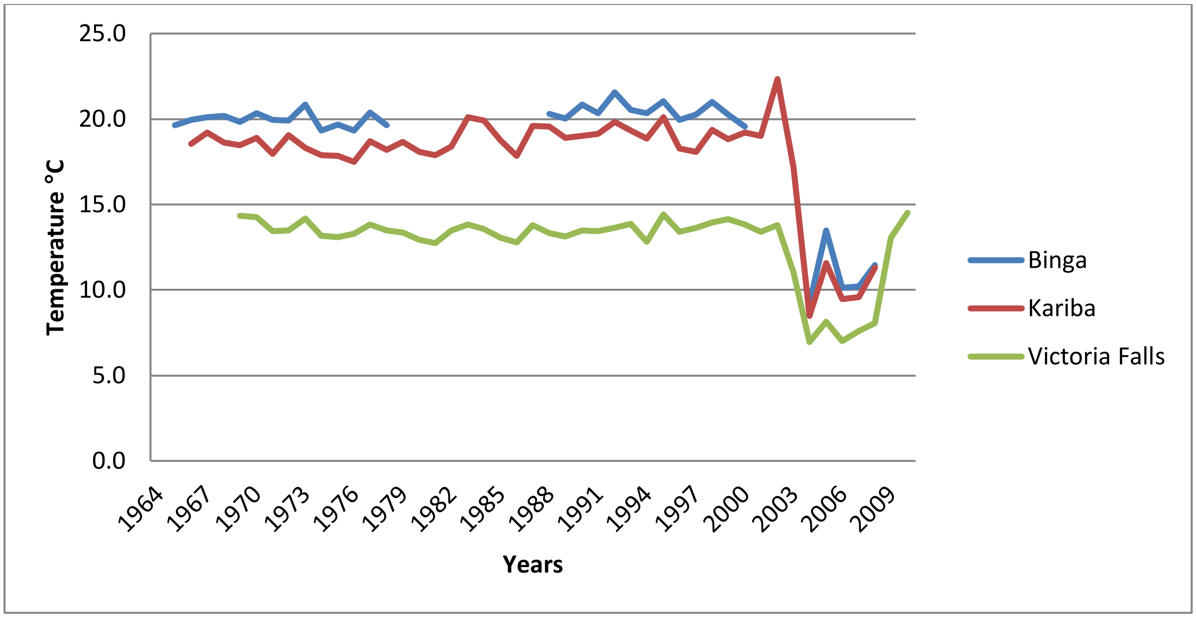

Figure 4.2.5 Long-term average annual minimum temperature patterns over the Kariba sub-basin
Source: Based on data from MSD (2018)

Table 4.2.2 Trend analysis for minimum temperature in the Kariba sub-basin (1964-2010)

Location	Meteorological Station	Years Recorded	Period	MK (Z)	Pvalue (MS)	Sen's SE (Q)	P-value (R)	tau
Victoria Falls	Victoria Falls Airport	1969-2010	Annual	-1.496		-0.017	0.13477	-0.161
		68/69-09/10	Wet season	-1.943	+	-0.041	0.033659	-0.229
		68/69-09/10	Dry Season	-1.300		-0.026	0.19343	-0.141
Kariba	Kariba Airport	1964-2008	Annual	-0.949		-0.016	0.34268	-0.099
		65/66-07/08	Wet season	0.293		0.003	0.7695	0.032
		65/66-07/08	Dry Season	-1.088		-0.034	0.27642	-0.116
Binga	Binga	1964-2008	Annual	-1.294		-0.025	0.057913	-0.200
		64/65-07/08	Wet season	-1.565		-0.089	0.0040198	-0.308
		64/65-07/08	Dry Season	-1.503		-0.041	0.016068	-0.258

Source: Based on data from MSD (2018)

Minimum temperatures for Victoria Falls in the wet season exhibit a statistically significant decreasing trend, as illustrated in Figure 4.2.6, with a p value of

0.033659 at α = 0.05 and negative Z statistic as in Table 4.2.2. However, the null hypothesis stood for the annual and dry minimum temperatures. Binga also showed a trend for both seasons. Nonetheless, the null hypothesis was rejected as no trend existed for the annual minimum temperature at 95% confidence level, but rather at 90%. No trend existed for Kariba station.

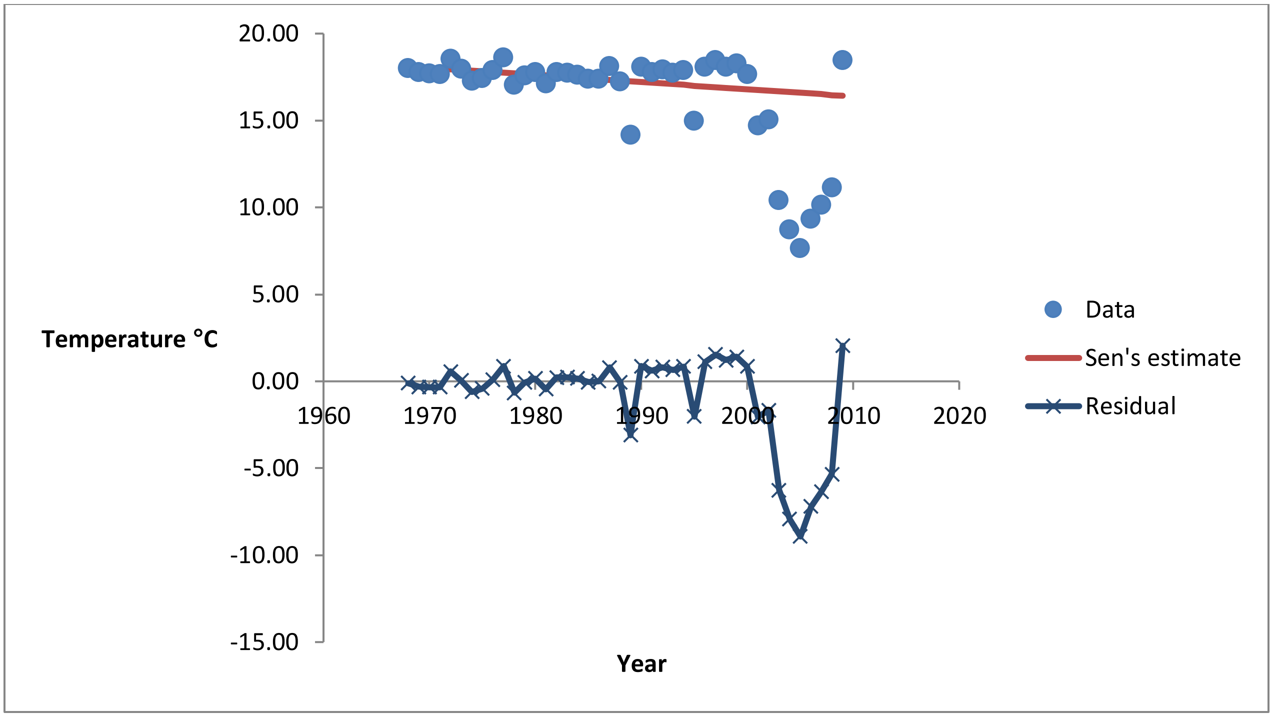

Figure 4.2.6 Trend and Sen's slope for Victoria Falls wet season minimum temperature (1964-2008)
Source: Based on data from MSD (2018)

4.2.2 Precipitation

Annual precipitation followed a similar pattern with years of low precipitation and spikes of high precipitation as illustrated in Figure 4.2.7. The years with low precipitation match the years of drought (1982/83,1991, 2002) and floods.

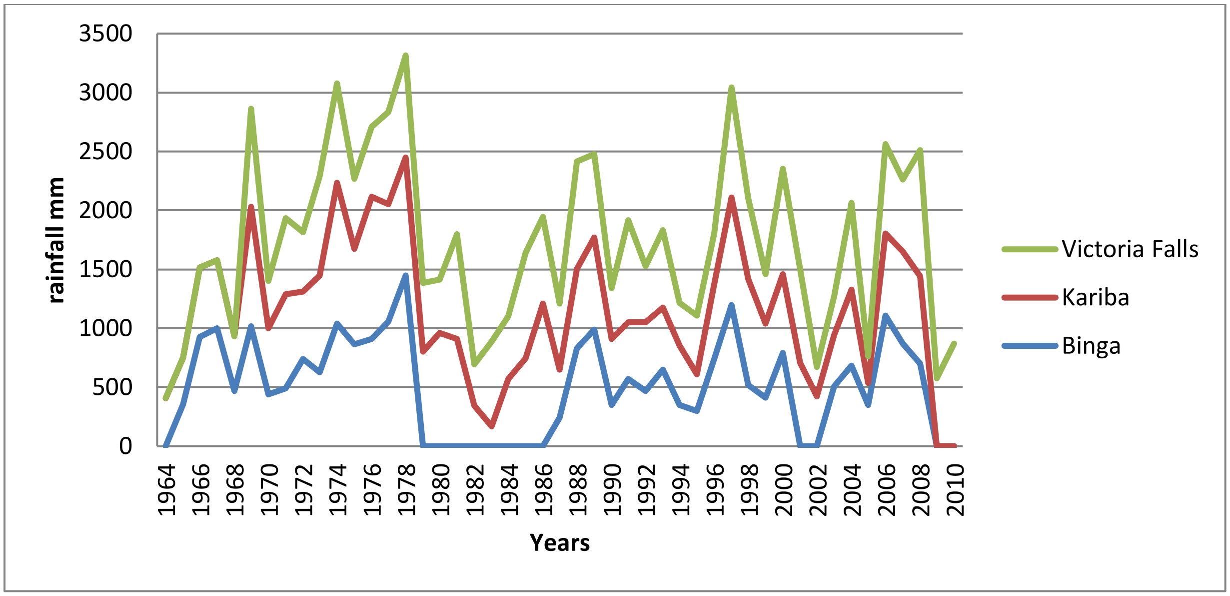

Figure 4.2.7 Long-term annual precipitation patterns over the Kariba sub-basin
Source: Based on data from MSD (2018)

Precipitation showed a decreasing trend as indicated by the negative Z statistic; however, it was not significant at alpha 0.05, as indicated in Table 4.2.3. A closer look at precipitation trends in Figure 4.2.8 shows a decreasing trend for Kariba in the wet season. However, the null hypothesis holds, as no significant trend was observed at alpha 0.05, but the trend is evident at alpha 0.1.

Table 4.2.3 Trend analysis for precipitation in the Kariba sub-basin (1964-2010)

Location	Meteorological Station	Years Recorded	Period	MK (Z)	Pvalue (MS)	Sen's SE (Q)	P-value (R)	tau
Victoria Falls	Victoria Falls Airport	1969-2010	Annual	-0.282		-1.408	0.77812	-0.031
		68/69-09/10	Wet season	0.108		0.055	0.9309	0.011
		68/69-09/10	Dry Season	-0.748		-0.167	0.4545	-0.081
Kariba	Kariba Airport	1964-2008	Annual	-0.714		-2.439	0.47516	-0.075
		64/65-07/08	Wet season	-1.689	+	-5.564	0.083368	-0.180
		64/65-07/08	Dry Season	-0.850		-0.156	0.38979	-0.091
Binga	Binga	1965-2008	Annual	-0.653		-2.925	0.23445	-0.127
		64/65-07/08	Wet season	-0.387		-2.061	0.2706	-0.119
		64/65-07/08	Dry Season	-1.506		-0.295	0.2773	-0.119

Source: Based on data from MSD (2018)

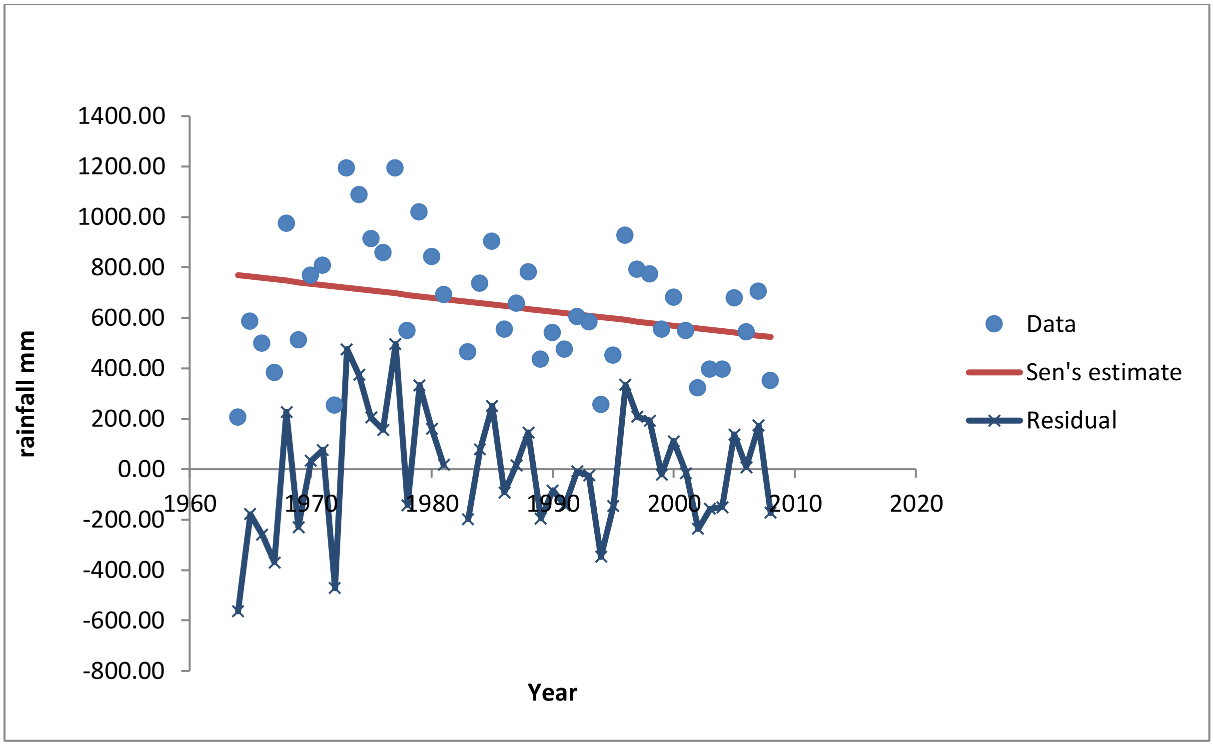

Figure 4.2.8 Trend and Sen's slope for Kariba Wet season precipitation (1964-2008)
Source: Based on data from MSD (2018)

4.2.3 River runoff

Of the rivers analysed, long term runoff data shows that most rivers receive their peak discharge around February, during the wet season, as shown in Figure 4.2.9. The Zambezi is unique as its peak discharge is in the dry season, around April and May. This speaks to the different variables that impact river runoff for the different rivers. Annual river runoff patterns in Figure 4.2.10 show high variability as the peaks and lows are not always consistent. It also speaks to multiple variables that impact river runoff compared to the climatic variables that had similar patterns.

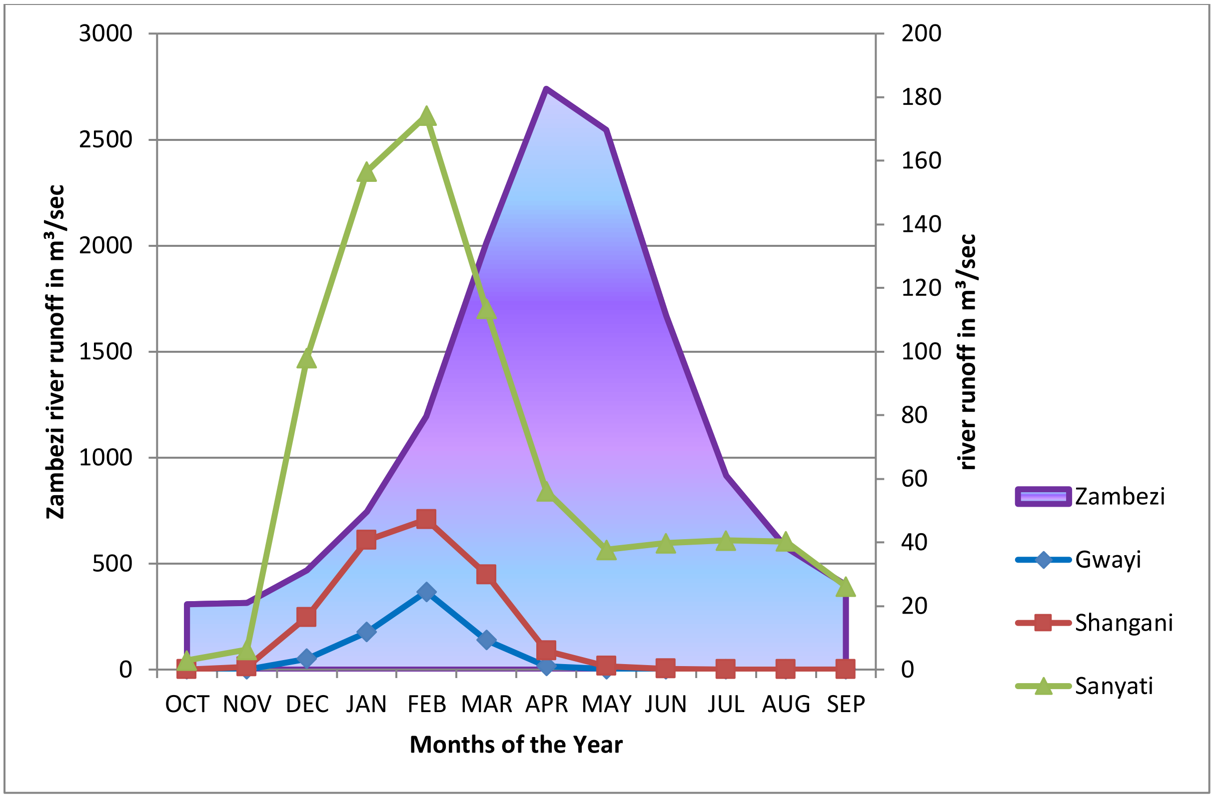

Figure 4.2.9 Average monthly river runoff in the Kariba sub-basin
Source: Based on data from ZINWA (2018)

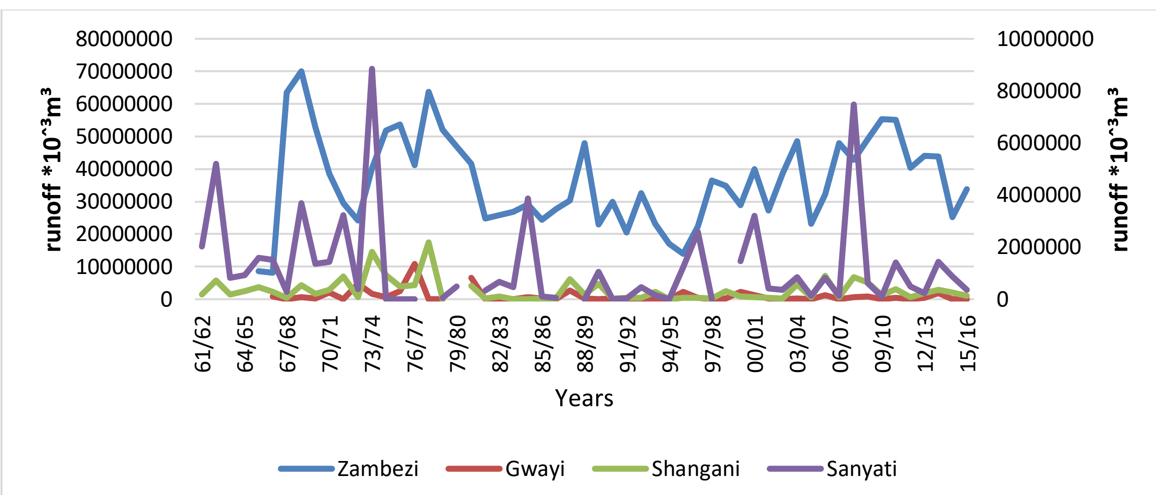

Figure 4.2.10 Annual river runoff in the Kariba sub-basin
Source: Based on data from ZINWA (2018)

River runoff on all rivers besides the Zambezi had a decreasing trend. The null hypothesis was only rejected for Sanyati, as it had a significant decreasing trend at alpha 0.05, as indicated in Table 4.2.4, with Sen's estimate in Figure 4.2.11. The Zambezi River showed an increasing trend, though not significant.

Table 4.2.4 Trend analysis for river runoff in the Kariba sub-basin (1961-2017)7

River	Gauging Station Location	Years Recorded	Period	MK (Z)	P-value (MS)	Sen's SE (Q)	P-value (R)	tau
Gwayi	Dahlia Control Sect	66/67-16/17	Annual Seasons	-1.037		-284.813	0.25549	-0.111
Shangani	Gwaai Confluence	61/62-16/17	Annual Seasons	-0.145		-377.722	0.78283	-0.026
Sanyati	Copper Queen C/S	61/62-15/16	Annual Seasons	-1.380		-10114.037	0.037543	-0.195
Zambezi	Victoria Falls Big Tree	65/66-15/16	Annual Seasons	0.195		35809.926	0.84545	0.020

Source: Based on data from ZINWA (2018)

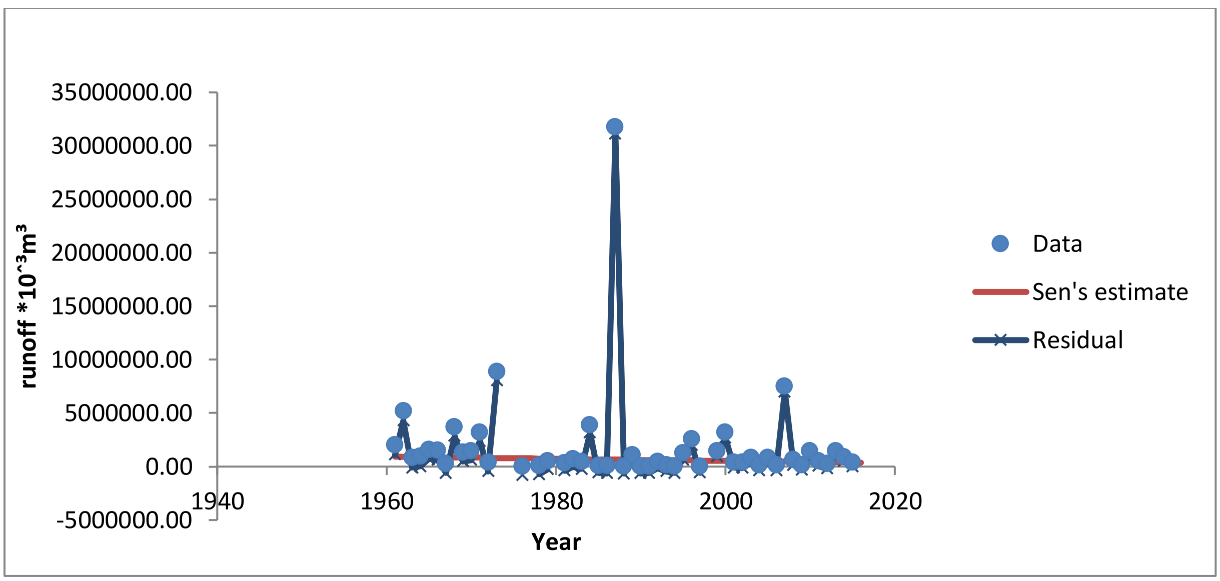

Figure 4.2.11 Annual river runoff at Sanyati
Source: Based on data from ZINWA (2018)

The Zambezi River is highly variable, and its long-term patterns show varying dips and peaks as illustrated in Figure 4.2.12. The dips are consistent with some drought years like 71/72, 91/92 and 95/96.

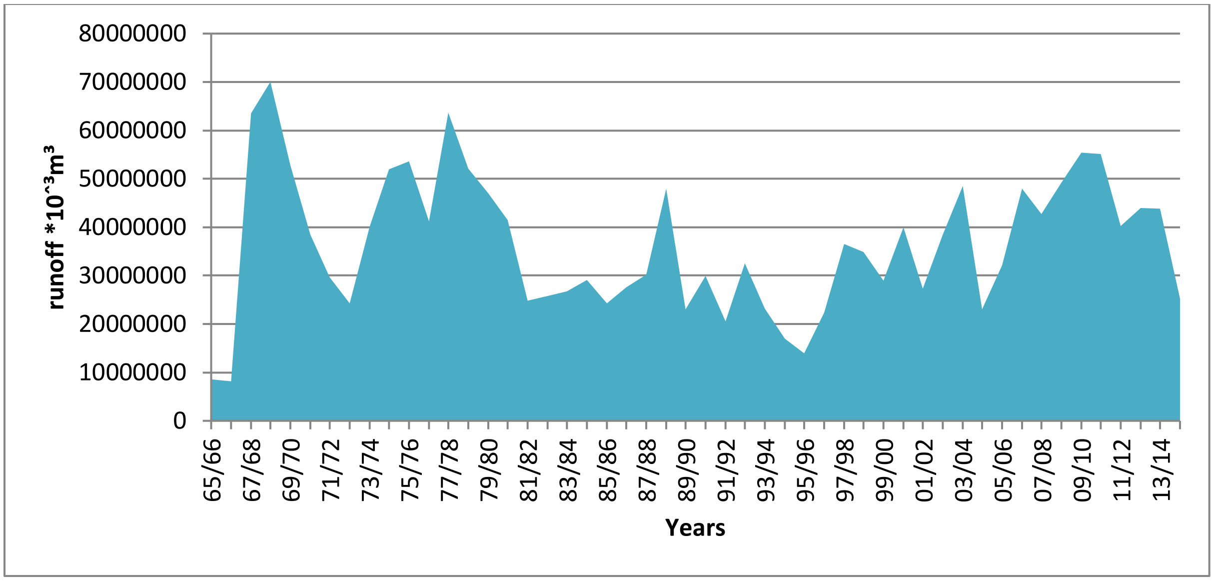

Figure 4.2.12 Zambezi annual river runoff
Source: Based on data from ZINWA (2018)

4.2.4 Hydropower generation

For hydropower generation, the null hypothesis was rejected as a significant negative trend exists for hydropower generation. Hydropower generation has been decreasing over the years, as indicated by Table 4.2.5 and illustrated by Figure 4.2.13. It was then important for the study to further explore the relationship between hydropower generation and hydroclimatic variables in the Kariba sub-basin.

Table 4.2.5 Trend analysis for annual hydropower generation in Zimbabwe (1961-2017)

Station	Years Recorded	Period	MK (Z)	P-value	Sen's (Q)	SE	P-value	Tau
Kariba (incl. SH)	1971-2015	Annual	-1.966	*	-0.643		0.04927	-0.204

Source: Based on data from World Bank website (2019)

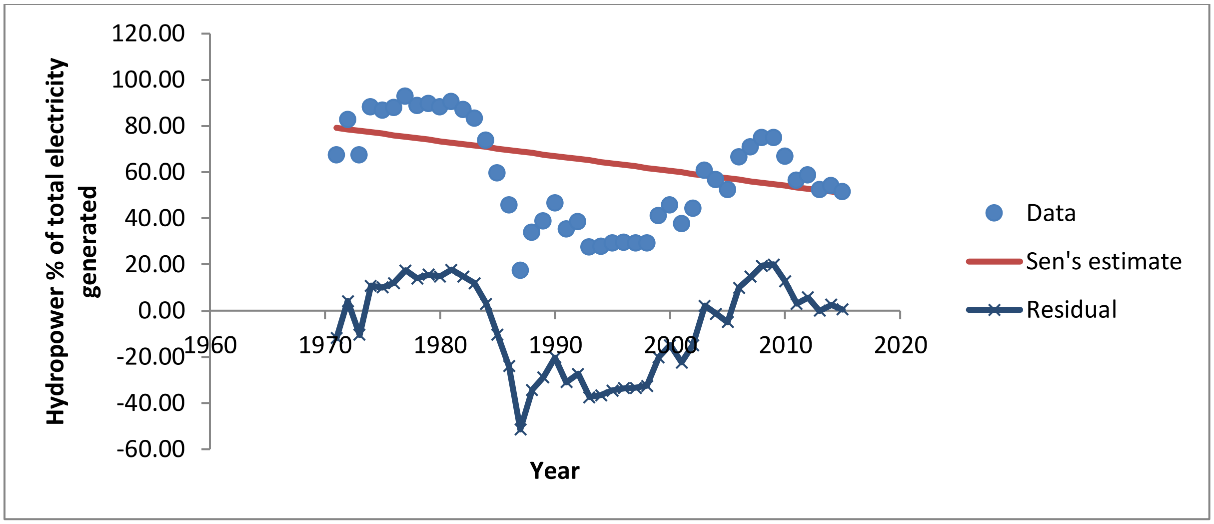

Figure 4.2.13 Annual hydropower generation in Zimbabwe
Source: Based on data from World Bank website (2019)

4.3 Exploring Climatic, Hydrological and Hydropower Generation Relationships in the Kariba Sub-Basin

4.3.1 Climatic variability on hydrological variability

The climate change–water–energy nexus is greatly influenced by the relationships between runoff, temperature and precipitation. The study analysed the relationships among these variables to establish the existence of a climate change–water–energy nexus. Both temperature and precipitation have a linear relationship with river runoff in Victoria Falls. A closer look at Table 4.3.1 shows that precipitation has direct proportionality to runoff because of the positive coefficient and p value <0.05. An increase in precipitation results in an increase in runoff. Temperature is inversely proportional because of the negative coefficient and p value < 0.05. Hence, an increase in temperature results in a decrease in runoff. According to the regression model, changes in temperature and precipitation explained 21% of the changes seen in river runoff. The results show a relationship between climatic and hydrological variables which has been of interest in the study, linking climate (temperature and precipitation) and water resources through river runoff.

Table 4.3.1 Effect of temperature and precipitation on runoff in Victoria Falls

Regression Statistics	
Multiple R	0,46258473
R Square	0,21398463
Adjusted R Square	0,17367615
Standard Error	11900677,1
Observations	42

ANOVA	*df*	*SS*	*MS*	*F*	*Significance F*
Regression	2	1,504E+15	7,518E+14	5,3086752	0,0091391
Residual	39	5,523E+15	1,416E+14		
Total	41	7,027E+15			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	81910812,4	21495419	3,8106172	0,0004803	38432224	125389401	38432224	125389401
Precipitation	25810,4064	10247,566	2,5186865	0,0159914	5082,7472	46538,066	5082,7472	46538,066
Temperature	-2197324	798247,51	-2,752685	0,0089258	-3811932	-582715,97	-3811932	-582715,97

Source: Based on data from MSD and ZINWA (2018)

4.3.2 Hydroclimatic variability on hydropower generation

4.3.2.1 Relationship of hydropower and river runoff

The analysis of the relationship between hydropower and runoff allowed the study the see how water influences electricity generated in the Kariba sub-basin. River runoff has a linear relationship with hydropower, indicated by p value <0.05 and a positive coefficient 9,66185E-07 in Table 4.3.2. According to the regression model, changes in runoff explained 27% of the changes seen in hydropower. This suggests a relationship between energy and water and has a bearing on energy security for Zimbabwe, which relies heavily on hydropower generated at Kariba Power station. Figure 4.3.1 illustrates this relationship, where hydropower output follows the same pattern as runoff.

Table 4.3.2 Regression of runoff on hydropower in Victoria Falls

Regression Statistics	
Multiple R	0,522709636
R Square	0,273225364
Adjusted R Square	0,256323628

ANOVA	*df*	*SS*	*MS*	*F*	*Significance F*
Regression	1	5804,890807	5804,890807	16,16552098	0,000230004
Residual	43	15440,90691	359,0908585		

Standard Error	18,94969283		Total	44	21245,79772			
Observations	45							

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	23,70421313	9,078872255	2,610920438	0,01238159	5,394922272	42,01350398	5,394922272	42,01350398
Runoff	9,66185E-07	2,40306E-07	4,020636887	0,000230004	4,81561E-07	1,45081E-06	4,81561E-07	1,45081E-06

Source: Based on data from ZINWA (2018) and World Bank 2019

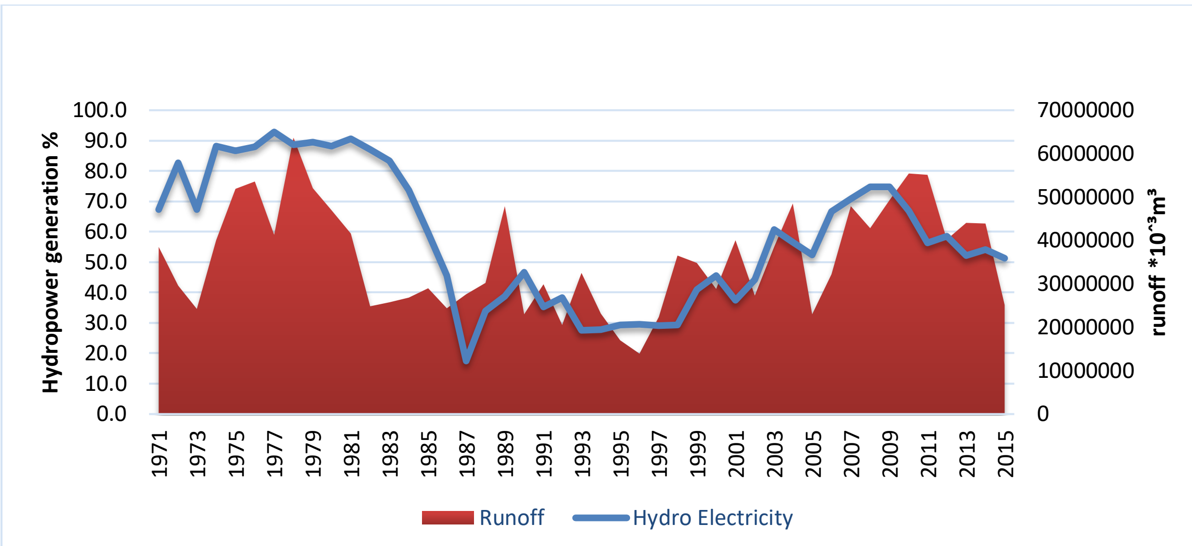

Figure 4.3.1 Hydropower and runoff trends in Victoria Falls
Source: Based on data from MSD and ZINWA (2018)

4.3.2.2 Hydropower, temperature, precipitation and river runoff relationships.

The study sought out to understand the hydroclimatic and energy generation patterns observed in the Kariba sub-basin and the relationships that existed between them. Analysis of the relationships that exist with hydropower generated temperature, precipitation and runoff was necessary to establish the existence of a climate change-water-energy nexus in the Kariba sub-basin. According to the regression model, changes in temperature, precipitation and river runoff explained 33% of the changes seen in hydropower. River runoff is an independent predictor of hydropower output as it is the only one with a p value

< 0.05 in Table 4.3.3. The coefficient of runoff was 1,07079E-06, remaining close to the coefficient 9,66185E-07 in the simple linear regression between runoff and hydropower in section 4.3.2.1. Temperature and precipitation do not have a direct effect on hydropower, but on river runoff, as was previously indicated in Table. 4.3.4. This indicates runoff as a major determinant of hydropower output.

Table 4.3.3 Regression of temperature, precipitation and runoff on hydropower in Victoria Falls11

Regression Statistics	
Multiple R	0,572085078
R Square	0,327281336
Adjusted R Square	0,271221447
Standard Error	19,86963397
Observations	40

ANOVA	*df*	*SS*	*MS*	*F*	*Significance F*
Regression	3	6914,646726	2304,882242	5,838066106	0,002340496
Residual	36	14212,88475	394,8023541		
Total	39	21127,53147			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	56,27280607	45,04378839	1,249291147	0,219620651	-35,08023095	147,6258431	-35,08023095	147,6258431
Runoff	1,07079E-06	2,9337E-07	3,649972558	0,000825649	4,7581E-07	1,66577E-06	4,7581E-07	1,66577E-06
Precipitation	-0,002272622	0,018902443	-0,120229016	0,904970237	-0,040608553	0,036063308	-0,040608553	0,036063308
Temperature	-1,182856082	1,594499097	-0,74183553	0,462999585	-4,416650135	2,05093797	-4,416650135	2,05093797

Source: Based on data from MSD and ZINWA (2018); World Bank (2019)

The linear regressions carried produced compelling results on the relationships that exist among climatic, hydrological and hydropower output variables. The significant relationship between temperature, precipitation and runoff and between runoff and hydropower at Victoria Falls establish the existence of a climate change-water-energy nexus. This, together with the decreasing trend in hydropower output, has implications on energy security in Zimbabwe. It then became important for the researcher to understand how energy insecurity impacts on urban livelihoods that depend on electricity in Zimbabwe, which is largely generated from hydropower.

4.4 Characteristics of Home-Based Informal Businesses in Harare

The study sought to characterise home-based informal businesses in Harare. The purpose was to find out who made up the home-based informal sector, as this group is understudied and overlooked in many population surveys.

4.4.1 Socioeconomic demographics

Of the households surveyed, 52% were female headed. Many of the women in the study were married, constituting 47% of households. The highest education level was high school, with most women being employed in the informal sector as represented in Table 4.4.1. The survey had an average of 2.37 males and 2.81 females per household, with an average of five people per household.

Table 4.4.1 Marital status, gender, level of education and employment status of women in home-based informal businesses12

Marital Status	Married	Single	Widowed	Divorced		N
	47.3%	23.3%	18.7%	10.7%		150
Education Level	Primary School	High School	Tertiary			
	3%	56%	41%			150
Employment Status	Full Time	Part Time	Informal	Unemployed	Retired/ Pensioner	
	21%	13%	60%	3%	3%	150
Mean Gender Distribution	Male	Female				
	2.27	2.81				

Source: Field survey (2018)

The survey was carried out on 150 households. Some households were not comfortable giving out information on their earnings, hence, only 116 households gave responses on their household income, earned in United States dollars (USD). Most of respondents' household incomes were between $501-1000, with MDRA households topping that level as illustrated in Figure 4.4.1. No households in LDRAs and MDRAs had household incomes at the lower end ($101-300). Only in HDRAs did a few households have a household income exceeding $5000.

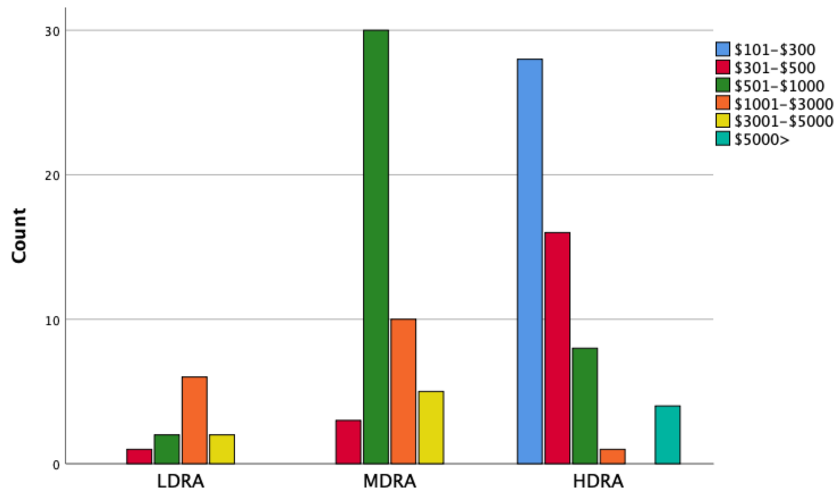

Figure 4.4.1 Household income in HDRAs, MDRAs and LDRAs (in USD)
Source: Field survey (2018)

Different households used various sources of income to sustain their livelihoods. The bulk of respondents' incomes were sourced from salaries and informal businesses. However, the LDRAs had more respondents that received remittances, while only 7% of HDRA respondents received pensions. A large number (76%) of MDRAs had savings as part of their source of income, as represented in Figure 4.4.2.

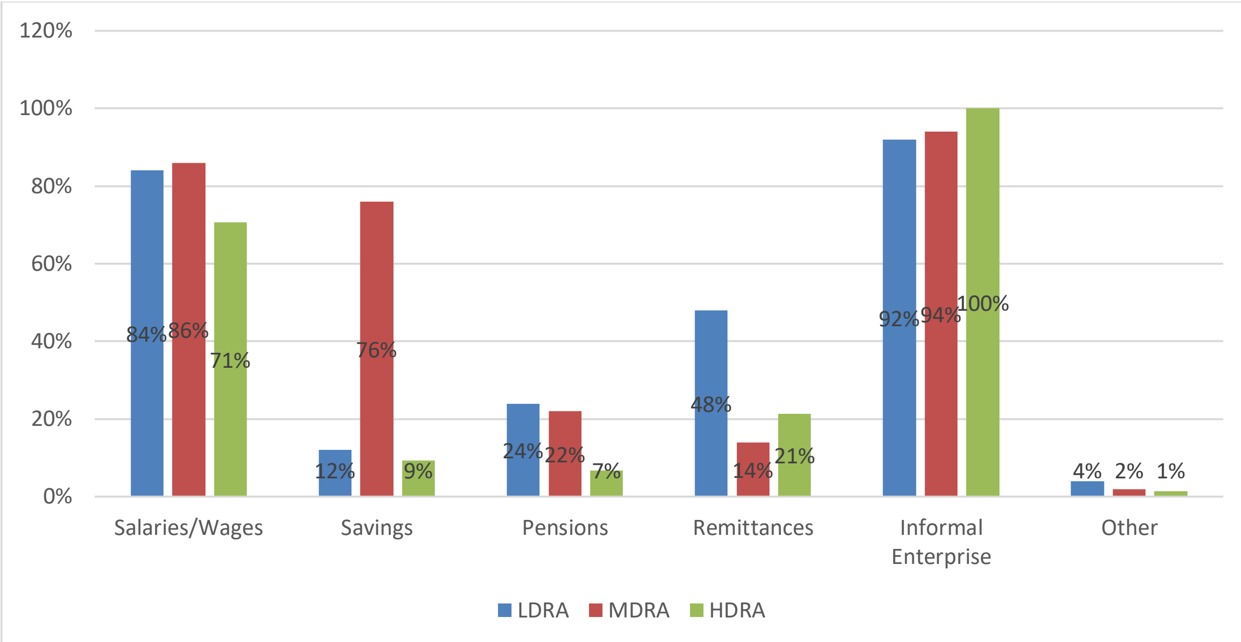

Figure 4.4.2 Responses on the multiple sources of income of households in the three different residential areas
Source: Field survey (2018)

Different households had access to credit, which varied across the residential areas. In the LDRAs, 72% of the respondents had access to credit, compared to 54% and 34.7% in the MDRAs and HDRAs, respectively. Put together, only 47.3% of the entire survey had access to credit. Property ownership in the different residential areas varied, with most residents in LDRAs having purchased the properties they lived in. Figure 4.4.3 shows that most respondents lived in homes that they had purchased. The LDRAs did not have any houses allocated to them. The ownership of other assets like cars was evident, with at least 44% of the households owning a vehicle. Only households in the LDRAs owned more than two cars.

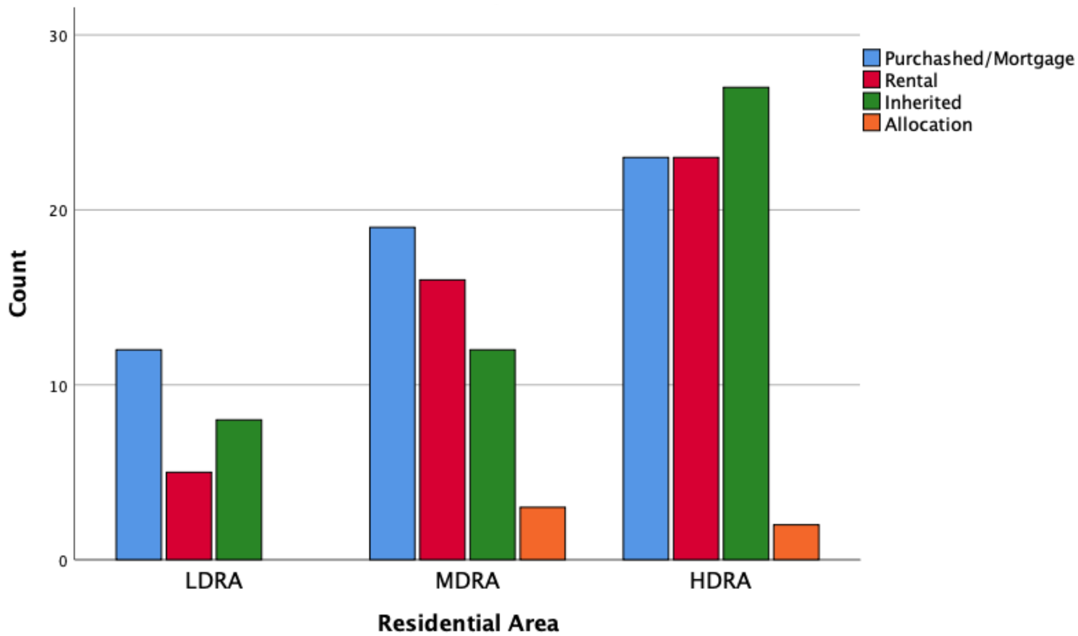

Figure 4.4.3 Property ownership of households
Source: Field survey (2018)

4.4.2 Structure and type of informal businesses

It was important to look at the enterprises in terms of their economic activities and employment structures. Informal businesses are comprised of different types and sizes of businesses. It was important to know which types were present, and their structure. It was also important to know what types of businesses the woman took part in. It informs on how they use electricity for their business. The survey found that home-based informal businesses are comprised of different types of business. Below, in Figures 4.4.4, 4.4.5 and 4.4.6, are pictures representing several businesses encountered during the survey. Poultry was a common business employed by women in home-based informal work. Although the market appeared to be flooded, it was still very common in all residential areas. Tailoring, from school uniforms to bedding and curtaining, was also a source of livelihood for women in informal work. It was considerably easy to establish a base at home as a room was allocated to tailoring by most households. At times, an assistant was employed when the household had many orders to clear. Welding and carpentry were not widely practiced by women;

however, a few businesses were run by women who had capital and space to run the business. Some carried on with this work after the death of a spouse. These businesses employed men or had the sons of the women handling the manual operations of the businesses and the women over-seeing the administrative side of the business.

Figure 4.4.4 Home-based chicken run
Photo by Memory Reid (2018)

Figure 4.4.5 home-based tailoring room
Photo by Memory Reid (2018)

Figure 4.4.6 Home-based welding business
Photo by Memory Reid (2018)

The survey had most businesses being own-account enterprises at 60% as shown in Table 4.4.2. A positive result from a chi-squared test indicated that a strong relationship between residential area and type of business exists as shown in Table 4.4.3. There was significant evidence of an association, (chi-sqaure (2) = 19.676, $p < 0.001$). Within HDRAs, 70% of businesses were own-account enterprises, with LDRAs recording no contributing family workers. It was important to know how long these businesses had been operating and how many people they employed. Table 4.4.3 indicates the average age of informal businesses at 6.67 years, with the oldest business being 20 years old. It also shows the average number of people employed in a business to be 1.77.

Table 4.4.2 Association between residential area and type of enterprise

			Type of enterprise			Total
			Own-Account Enterprise	Enterprise of Employers	Contributing Family Workers	
Residential Area	LDRA	Count	11	14	0	25
		% within Residential Area	44.0%	56.0%	0.0%	100.0%
	MDRA	Count	26	19	5	50
		% within Residential Area	52.0%	38.0%	10.0%	100.0%
	HDRA	Count	53	11	11	75
		% within Residential Area	70.7%	14.7%	14.7%	100.0%
Total		Count	90	44	16	150
		% within Residential Area	60.0%	29.3%	10.7%	100.0%
Chi-Square Tests						
	Value	df	Asymptotic Significance (2-sided)			
Pearson Chi-Square	19.676a	4	.001			
Likelihood Ratio	22.134	4	.000			
Linear-by-Linear Association	1.032	1	.310			
N of Valid Cases	150					
a 1 cells (11.1%) have expected count less than 5. The minimum expected count is 2.67.						
Symmetric Measures						
		Value	Approximate Significance			
Nominal by Nominal	Phi	.362	.001			
	Cramer's V	.256	.001			
	Contingency Coefficient	.341	.001			

Source: Field survey (2018)

Table 4.4.3. Operation period and number of people employed in informal businesses

	N	Range	Minimum	Maximum	Mean

	Statistic	Statistic	Statistic	Statistic	Statistic
Operation period	150	20	0	20	6.67
Number of people employed in enterprise	150	5	1	6	1.77

Source: Field survey (2018)

Informal business do not usually require skilled labour which, at times, includes family members. A close look at Figure 4.4.7 shows most employees had a high school education, closely followed by tertiary. Most enterprises involved a huge contribution from family members. The majority of business owners did not have any skills training in the work they did. Nonetheless, the employees skills training was similar to those without training, as illustrated in Table 4.4.4.

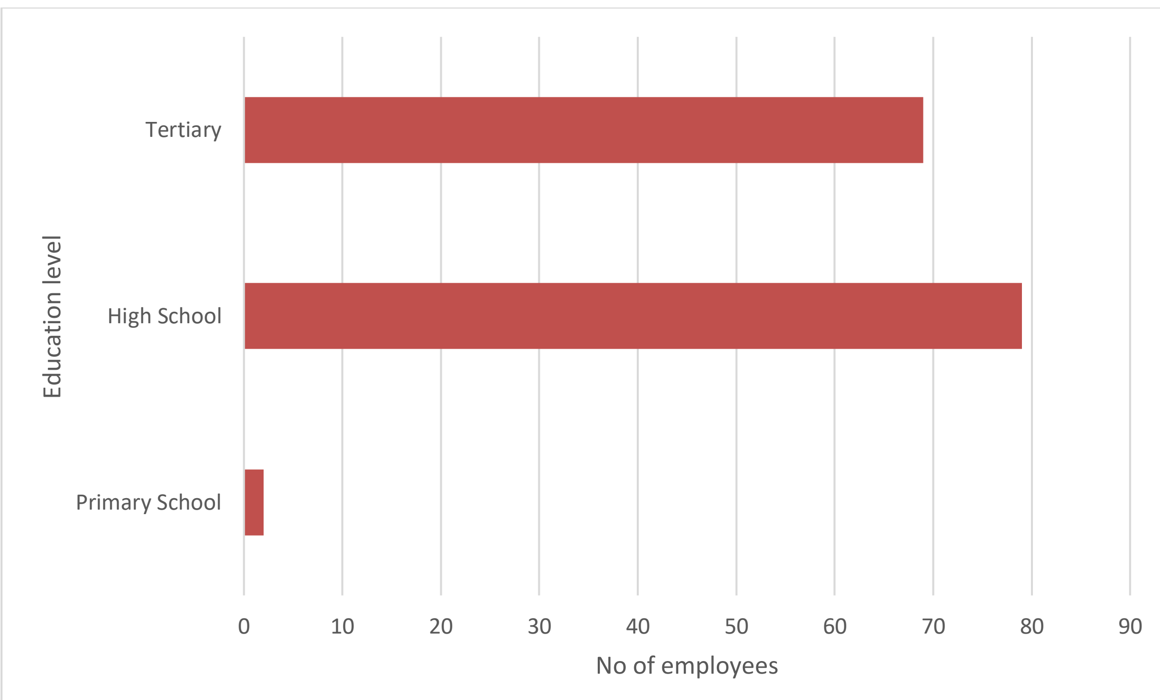

Figure 4.4.7 Highest level of education of employees in enterprise
Source: Field survey (2018)

Table 4.4.4 Family contribution and training skills in business enterprise

	N	Yes	No	N/A

Family members contribution to enterprise	150	68.7%	31.3%	
Business owner skills/training	150	48.0%	52.0%	
Employee's skills/training	150	20.0%	20.7%	59.3%

Source: Field survey (2018)

Informal businesses do not usually come with benefits as illustrated in Figure 4.4.8. The two exceptions were in cases where the employer was the sole proprietor and contributed to a pension fund. The other received allowances for transport from the employer.

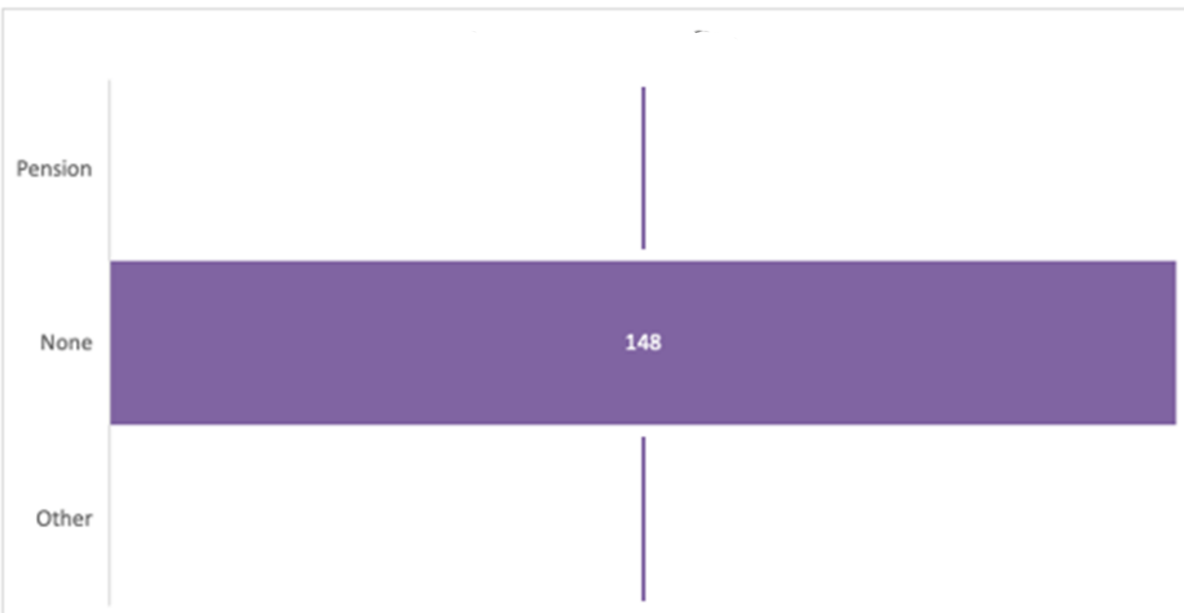

Figure 4.4.8. Employee benefits in the informal sector
Source: Field survey (2018)

Capital to start businesses was a challenge, as most businesses did not have access to credit or funding. Most women used their own capital to start their businesses, represented in Figure 4.4.9. Borrowing from friends was the second highest option used. Table 4.4.5 shows how there are no rules of entry into business, with little regulation in terms of licensing as most businesses mainly operated at home. However, where rules applied, they involved hygiene practices. Licensing applied to businesses recognised by a supporting body like the businesses that make textile and art pieces, which also included jewellery and beadwork. Most businesses operated from home with the exception of a few which included tailoring and catering that had shops or rental space, mainly in the CBD.

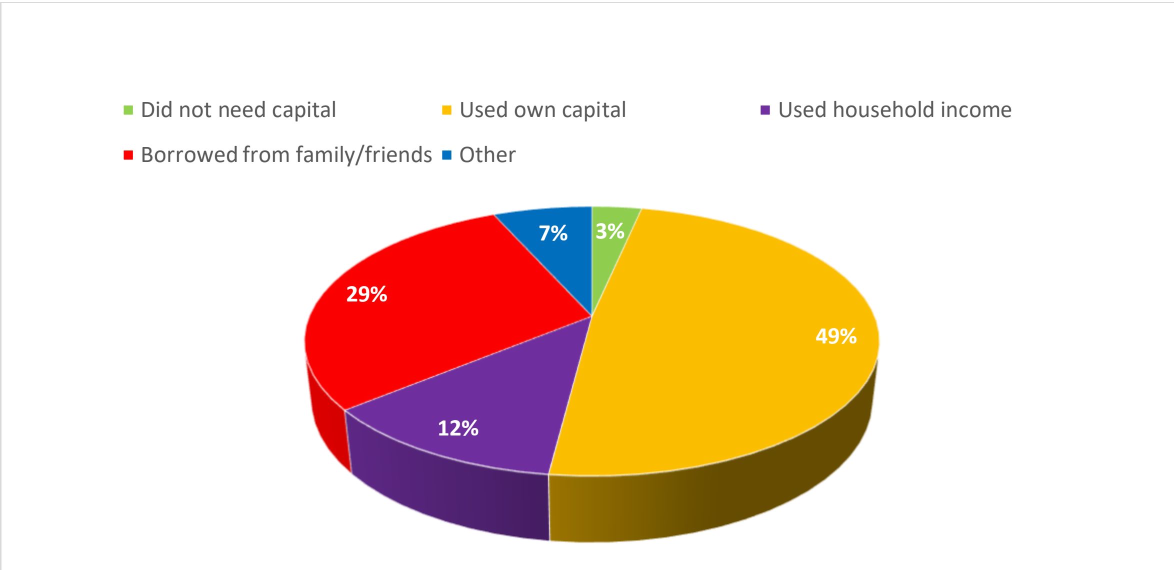

Figure 4.4.9 Sources of capital to start business
Source: Field survey (2018)

Table 4.4.5 Rules and location of informal businesses

	N	Yes	No
Rules of entry into the business	150	2.7%	97.3%
Operation of business from home only	150	81.3%	18.7%
License to run business	150	1.3%	98.7%

Source: Field survey (2018)

The study stems from looking at different home-based energy dependent businesses practiced by women in urban areas. Figure 4.4.10 shows the most popular business was tailoring, closely followed by catering and hairdressing. Retailing, food processing, poultry, carpentry/welding and recording studios were also visibly common.

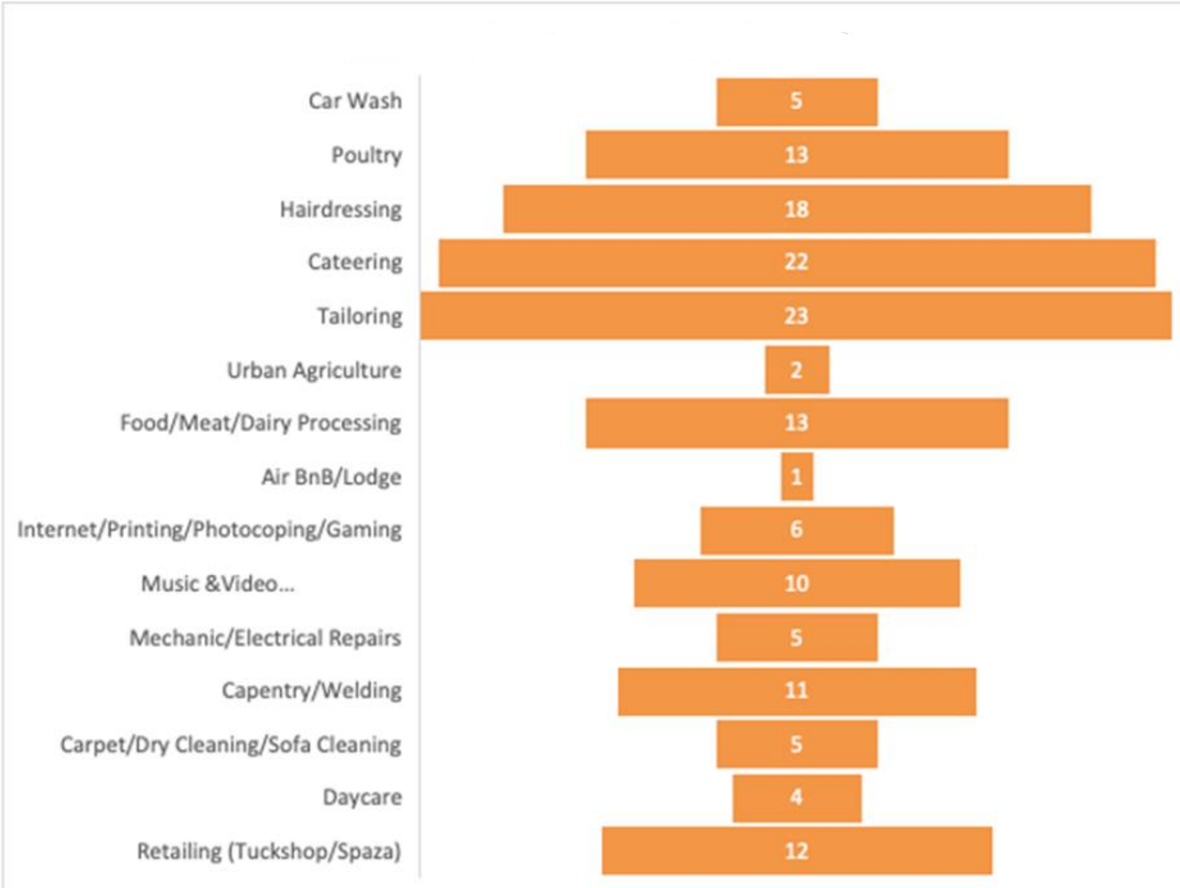

Figure 4.4.10. Description of home-based electricity dependent informal businesses practiced by women
Source: Field survey (2018)

The majority of the women sold or traded from their residences, as illustrated in Figure 4.4.11. Others had stalls in the community. Some businesses traded on sites where service was given. For example, hairdressers attended to their clients at their homes or place of event. The women in these businesses sourced their material from various buyers. Knowledge of their sources of material showed the researcher what it takes to source the materials required to run their business.

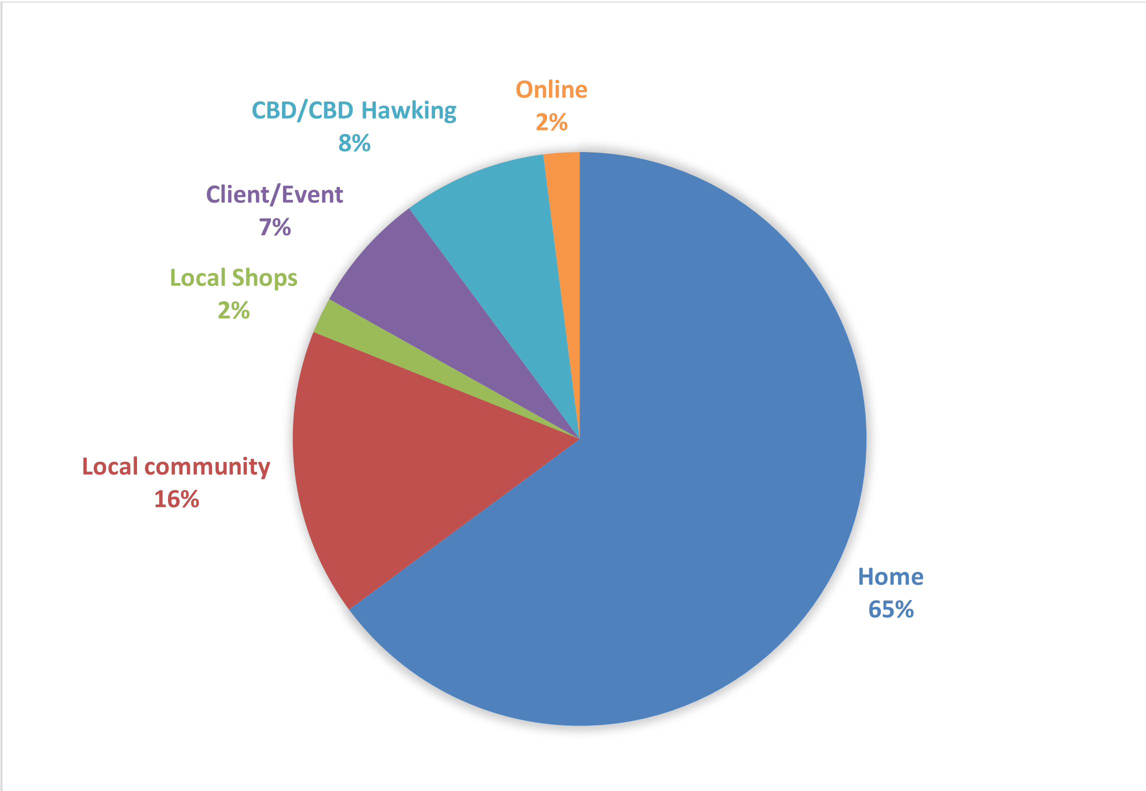

Figure 4.4.11 Location of sales of product or service provision
Source: Field survey (2018)

Figure 4.4.12 shows that most businesses sourced materials from wholesalers. The challenges they faced to source these raw materials are presented in Figure 4.4.13. It shows the cost of raw materials as the biggest obstacle they faced. Prices were exorbitant, with little room for reasonable profits. Transport or location of the raw materials impacted most women in the informal business.

Figure 4.4.12 Sources of raw materials for informal businesses
Source: Field survey (2018)

Figure 4.4.13 Challenges sourcing raw materials for informal businesses
Source: Field surveys (2018)

Debt from non-paying customers posed a challenge for businesses in their efforts to sustain their livelihoods, as illustrated by Figure 4.4.14. Many goods sold by informal businesses are flooded, hence, recouping significant profits from sales is a challenge. Customers tended to not want to pay full price for items, hence, profits were lost through negotiating on prices.

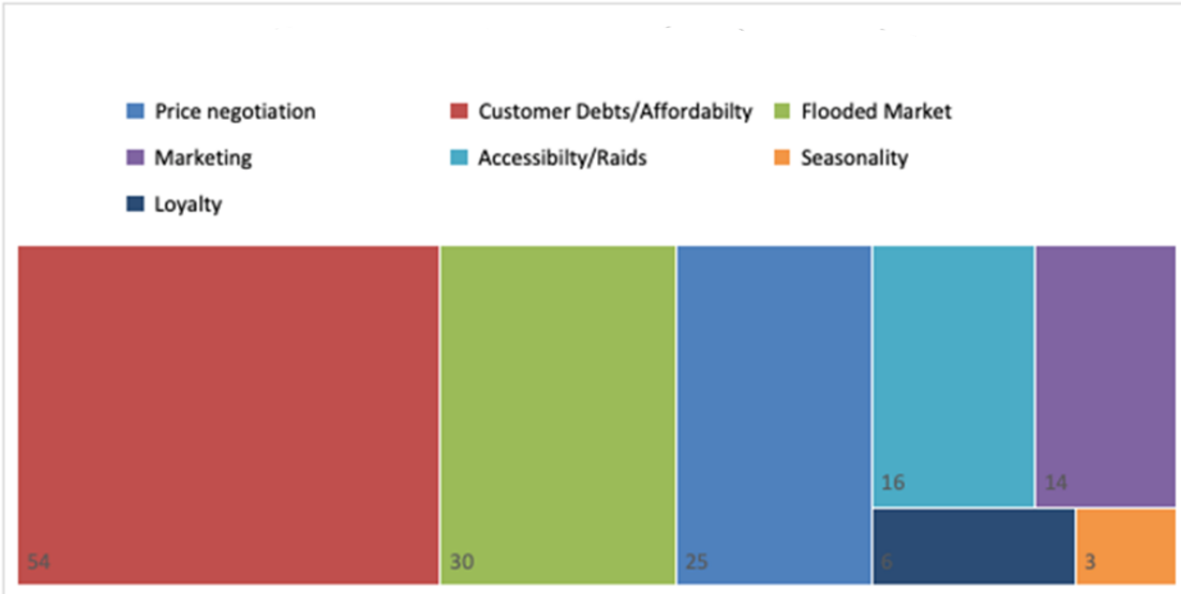

Figure 4.4.14 Challenges faced by informal businesses in selling their produce or providing their service
Source: Field survey (2018)

4.4.3 Income from informal businesses

Survey responses regarding income from informal business varied. Of the 150 questionnaires administered, only 117 responded on income from informal business. A close look at Table 4.4.6 shows most informal businesses generated a monthly income that ranged between \$300-500, closely followed by \$101-\$300. However residential area influenced income generated by the businesses. There was significant evidence of a strong association (chi-square (8) = 58.242, $p < 0.00$; likelihood ratio (8) =69.351, $p < 0.00$; Cramer's V=0.499) between residential area and income from informal business. This was reflected by higher earnings in LDRAs and MDRAs when compared to the HDRAs. In LDRAs and MDRAs 70% and 60% of the businesses made between \$301-\$500 monthly respectively, whereas in HDRAs, 35.1% of businesses earned less than \$100 and 40.4% earned \$101-300. Furthermore, high earnings of \$1001-3000 were made by 20% of businesses in LDRAs, with the other areas making only 8% and 7 %. Therefore, the data suggests that most businesses in LDRAs and MDRAs earned incomes in the upper categories compared to those in HDRAs.

Operating businesses during power cuts, significantly contributed to monthly income. This was evident as there was significant evidence of a strong association, (chi-square (8) = 16.906a, p=0.031; likelihood ratio (8) =16.927, p=0.031; Cramer's V=0.269) between monthly income and business operation during power cuts as illustrated in Table. 4.4.7. The data suggests that businesses that used manual equipment or substituted energy sources during power cuts earned more money than those that did nothing. The businesses that did nothing mostly had income in the <$100 and $101-$300 category (14.8% and 44.4%), whereas 11.5% of those that used manual equipment or substituted energy sources, between $1001-$3000 respectively. This suggests that having alternative methods to continue working during power cuts was advantageous as it secured more income versus not doing anything during power cuts.

Table 4.4.6 Monthly income from informal businesses in the different residential areas17

			Total monthly income from informal enterprise.					Total
			<$100	$101-$300	$301-$500	$501-$1000	$1001-$3000	
Residential Area	LDRA	% within Residential Area	0.0%	10.0%	70.0%	0.0%	20.0%	100.0%
	MDRA	% within Residential Area	0.0%	12.0%	60.0%	20.0%	8.0%	100.0%
	HDRA	% within Residential Area	35.1%	40.4%	10.5%	7.0%	7.0%	100.0%
Total		% within Residential Area	17.1%	25.6%	36.8%	12.0%	8.5%	100.0%
Chi-Square Tests								

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	58.242a	8	.000
Likelihood Ratio	69.351	8	.000
Linear-by-Linear Association	24.643	1	.000
N of Valid Cases	117		
a 7 cells (46.7%) have expected count less than 5. The minimum expected count is .85.			
Symmetric Measures			
		Value	Approximate Significance
Nominal by Nominal	Phi	.706	.000
	Cramer's V	.499	.000
	Contingency Coefficient	.576	.000
N of Valid Cases		117	

Source: Field survey (2018)

Table 4.4.7 Association of income from informal business and mode of operation during power cuts

			Total monthly income from informal enterprise.					Total
			<$100	$101-$300	$301-$500	$501-$1000	$1001-$3000	
Business operation during power cuts	Manual Equipment	% within Business operation during power cuts	41.7%	8.3%	25.0%	25.0%	0.0%	100.0%
	Substitute Energy Source	% within Business operation during power cuts	14.1%	21.8%	39.7%	12.8%	11.5%	100.0%
	Nothing	% within Business operation during power cuts	14.8%	44.4%	33.3%	3.7%	3.7%	100.0%
Total		% within Business operation during power cuts	17.1%	25.6%	36.8%	12.0%	8.5%	100.0%
Chi-Square Tests								
	Value	df	Asymptotic Significance (2-sided)					

Pearson Chi-Square	16.906a	8	.031
Likelihood Ratio	16.927	8	.031
Linear-by-Linear Association	.393	1	.531
N of Valid Cases	117		
a 8 cells (53.3%) have expected count less than 5. The minimum expected count is 1.03.			
Symmetric Measures			
		Value	Approximate Significance
Nominal by Nominal	Phi	.380	.031
	Cramer's V	.269	.031
	Contingency Coefficient	.355	.031
N of Valid Cases		117	

Source: Field survey (2018)

4.5 Energy Security and Urban Livelihoods

4.5.1 Energy insecurity and its impacts on informal businesses

A majority of the enterprises use electricity to operate their machines. However, electricity is used as a source of energy in multiple ways to accomplish different goals. Figure 4.5.1 illustrates how electricity was used by the various informal businesses run by women in their households.

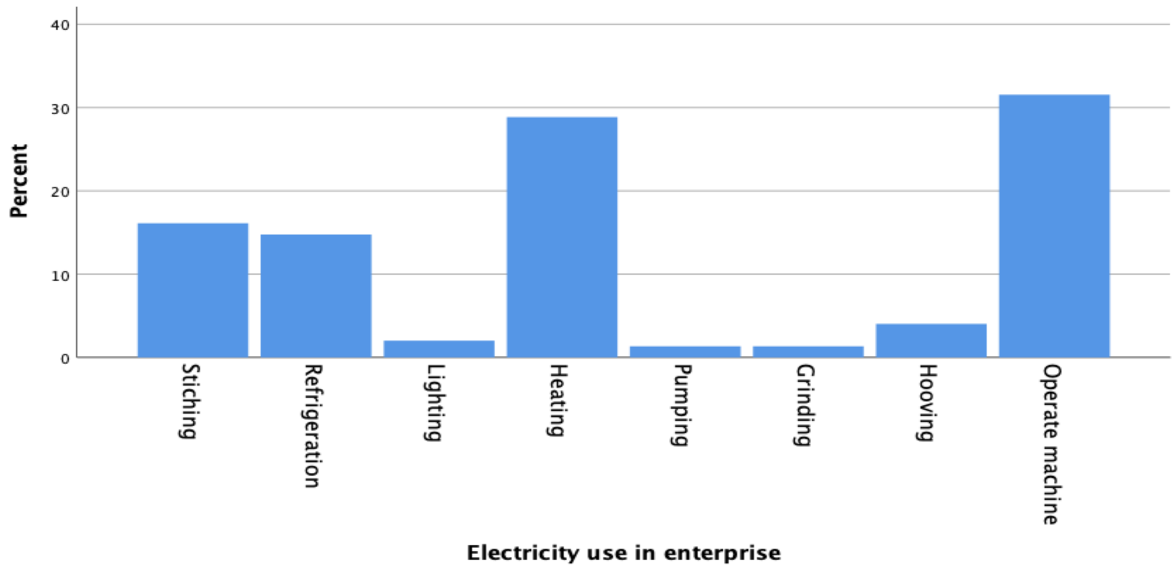

Figure 4.5.1 different electricity uses in the enterprise
Source: Field survey (2018)

Different households had various experiences of load shedding, as indicated in Figure 4.5.2. The duration of these power cuts ranged from zero to eight hours, with an average of 3.74hrs.

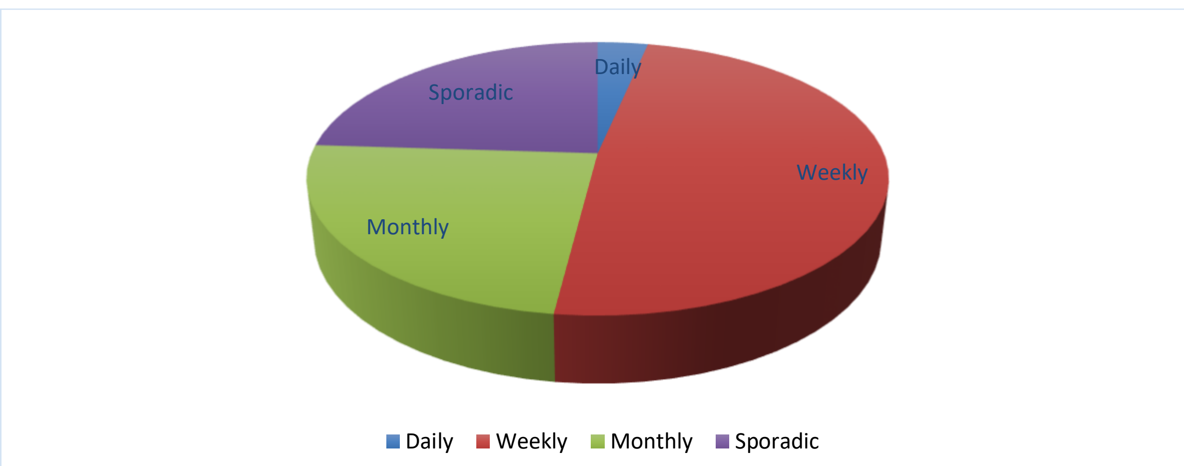

Figure 4.5.2 Frequency of power cuts experienced by home-based informal businesses
Source: Field survey (2018)

Businesses were perceived to experience more load shedding in winter, as indicated in Figure 4.5.3, than in any other period. Most businesses perceived the year 2016 as having the worst load shedding. Figure 4.5.4 also shows 2013, 2015 and 2017 as the other years with the worst load shedding.

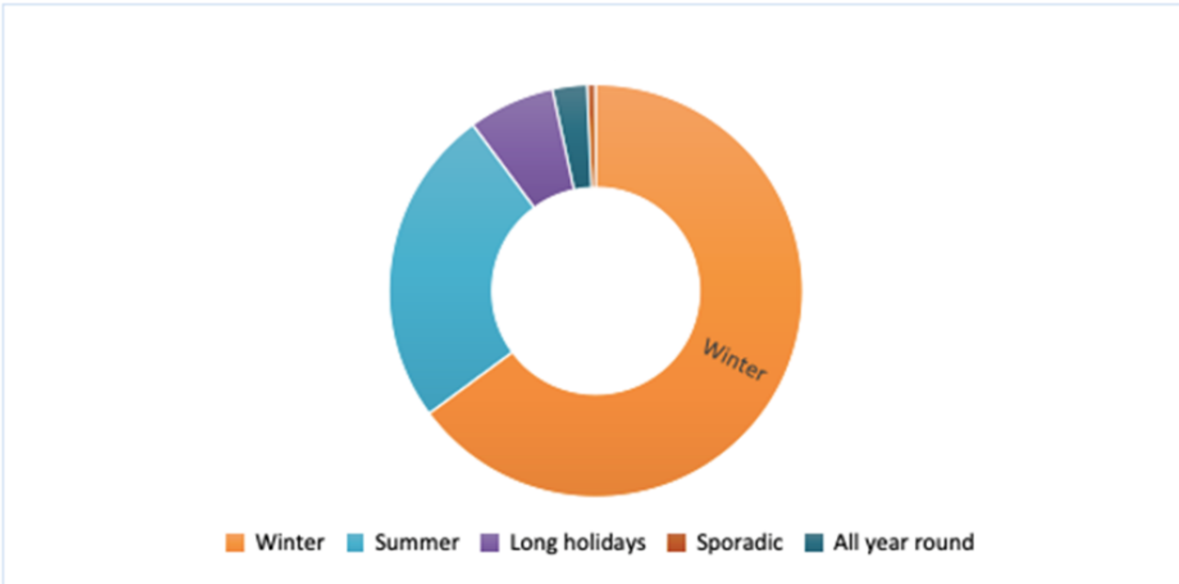

Figure 4.5.3 period when businesses experienced the worst load shedding/power outages in the year
Source: Field survey (2018)

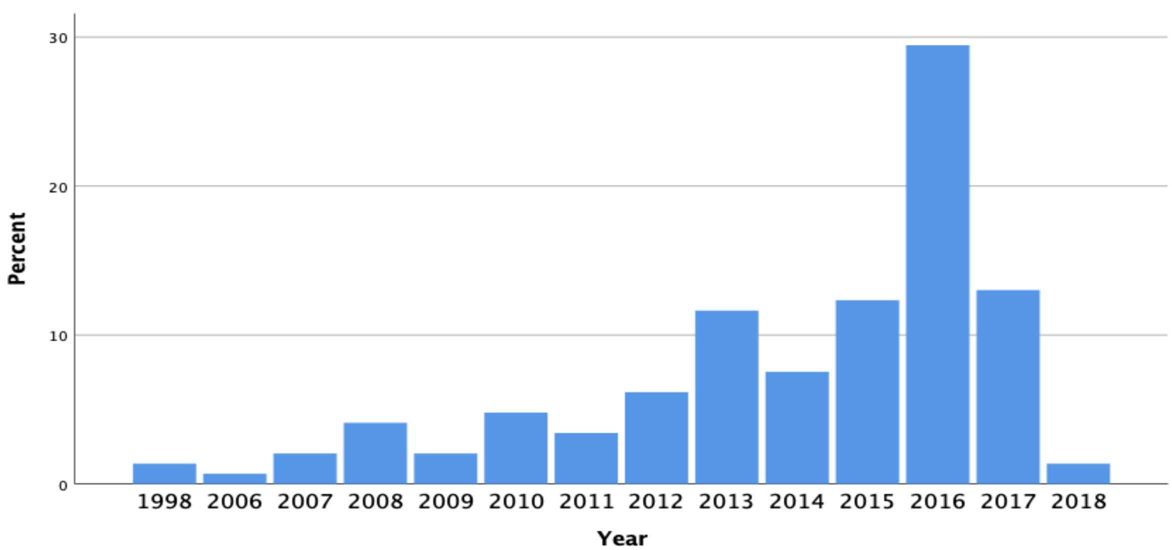

Figure 4.5.4 Frequency of years with worst load shedding
Source: Field survey (2018)

4.5.2 Adaptation and resilience

Businesses had to find ways to stay open during load shedding. The majority, 63%, substituted energy sources, while the rest used manual equipment or did nothing as they could not afford alternatives. This is illustrated in Table 4.5.1 and further demonstrated by Figure 4.5.5.

There was significant evidence of a strong association, (chi-square (4) = 21.171, p=0.00; likelihood ratio (4) =23.784, p=0.00; Cramer's V=0.266) as shown in Table 4.5.1. between business operation during load shedding and residential area. Within LDRAs and MDRAs, 76% and 80% of businesses used substitutes for electricity respectively. Only 48% of businesses in HDRAs could substitute for electricity, but most rather used manual equipment or did nothing. There is a high possibly that those that did nothing generated little income. This is most likely true as a strong association between income and operation during load shedding is indicated in Table 4.4.8. in the previous section.

Table 4.5.1 Association between residential area and business operation during load shedding

			Business operation during load shedding/power outages			Total
			Manual Equipment	Substitute Energy Source	Nothing	
Residential Area	LDRA	% within Residential Area	4.0%	76.0%	20.0%	100.0%
	MDRA	% within Residential Area	2.0%	80.0%	18.0%	100.0%
	HDRA	% within Residential Area	26.7%	48.0%	25.3%	100.0%

Total		% within Residential Area	14.7%	63.3%	22.0%	100.0%
Chi-Square Tests						
	Value	df	Asymptotic Significance (2-sided)			
Pearson Chi-Square	21.171a	4	.000			
Likelihood Ratio	23.784	4	.000			
Linear-by-Linear Association	2.478	1	.115			
N of Valid Cases	150					
a 1 cells (11.1%) have expected count less than 5. The minimum expected count is 3.67.						
Symmetric Measures						
		Value	Approximate Significance			
Nominal by Nominal	Phi	.376	.000			
	Cramer's V	.266	.000			
	Contingency Coefficient	.352	.000			
N of Valid Cases		150				

Source: Field survey (2018)

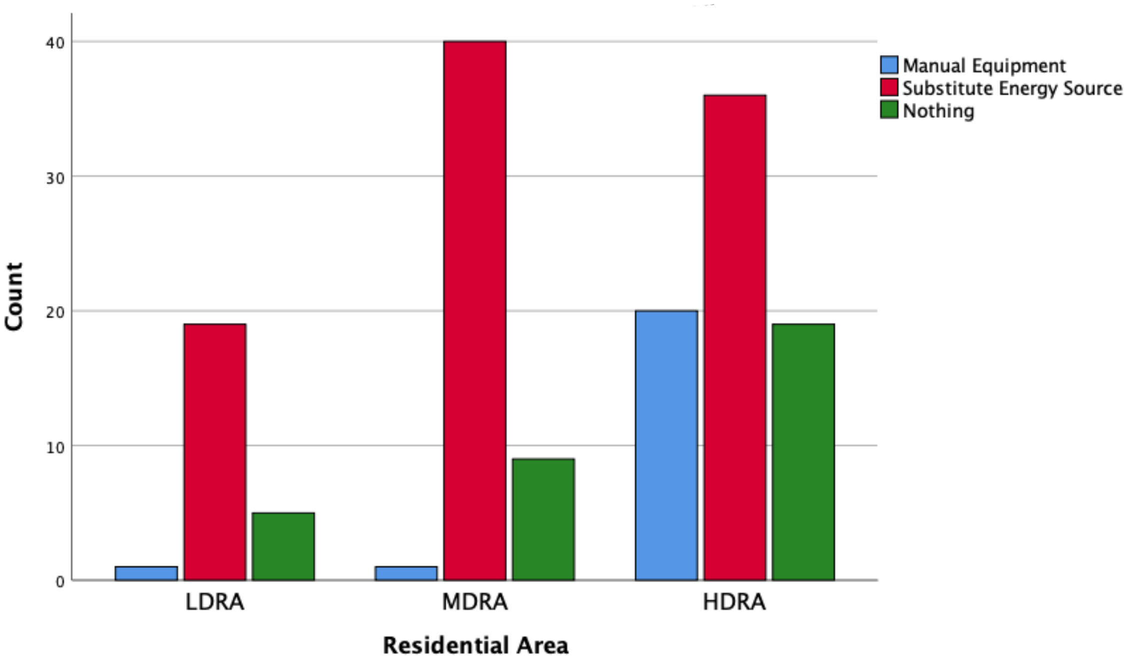

Figure 4.5.5 Association between business operation during load shedding residential area
Source: Field survey (2018)

During load shedding, the businesses that substituted for electricity mainly opted for generators. However, the choice of substitute also had a significant association with the residential area. In Table 4.5.2, there was significant evidence of a strong association, (chi-square (10) = 33.842, p=0.00; likelihood ratio (10) =36.199, p=0.00; Cramer's V=0.336). The businesses operating in LDRAs and MDRAs opted for generators compared to those in HDRAs which opted for firewood/charcoal as shown in Figure 4.5.6, suggesting a cheaper alternative was chosen.

Table 4.5.2 Association between residential area and electricity substitute

			Energy source substitute		
			N/A	Generator	Gas
			5	12	4
Residential Area	LDRA	% within Residential Area	20.0%	48.0%	16.0%
	MDRA	% within Residential Area	16.0%	52.0%	14.0%
	HDRA	% within Residential Area	46.7%	16.0%	6.7%
Total		% within Residential Area	32.0%	33.3%	10.7%

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	33.842a	10	.000
Likelihood Ratio	36.199	10	.000
Linear-by-Linear Association	.002	1	.963
N of Valid Cases	150		

a 6 cells (33.3%) have expected count less than 5. The minimum expected count is 1.67.

Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	.475	.000
	Cramer's V	.336	.000
	Contingency Coefficient	.429	.000
N of Valid Cases		150	

Source: Field survey (2018)

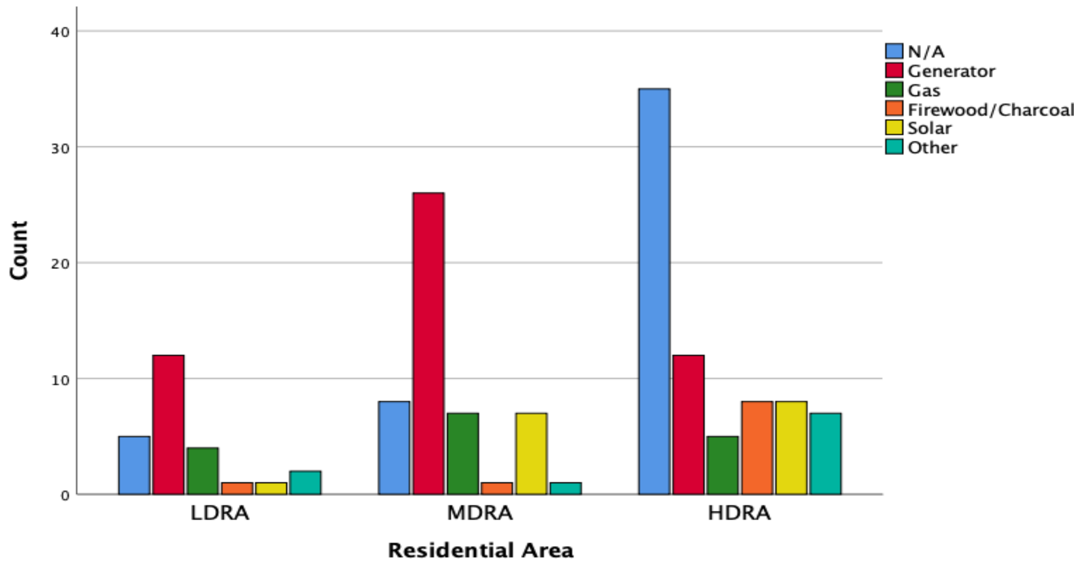

Figure 4.5.6 Types of electricity substitutes in different residential areas
Source: Field survey (2018)

Load shedding had various effects on home-based informal businesses. A closer look at Table 4.5.3. shows that load shedding impacted on informal businesses in several ways. The majority (44%) that substituted energy source found it to be costly and increased operational costs to make up for the additional cost incurred. Load shedding decreased production (78%) and declined income earned (75.2%) by home-based informal businesses.

Table 4.5.3 Perceptions on impact of load shedding

	N	Yes	No	N/A
Expense of substitute energy source	150	44.0%	20.7%	35.3%
Increase in operational cost	150	44.7%	20.7%	34.7%
Decline in production due to load shedding/power outages	150	78.0%	22.0%	
Decline in income due to load shedding/power outages	150	75.2%	24.8%	

Source: Field survey (2018)

Businesses adapted differently to income losses in their business. A closer look at Figure 4.5.7 highlights that most businesses opted to increase the cost of their products or services to make up for loss of income due to electricity cuts. Working overtime when power returned and diversifying income generating projects in the household were some of the other measures incorporated by households that depend on informal businesses as their sources of income.

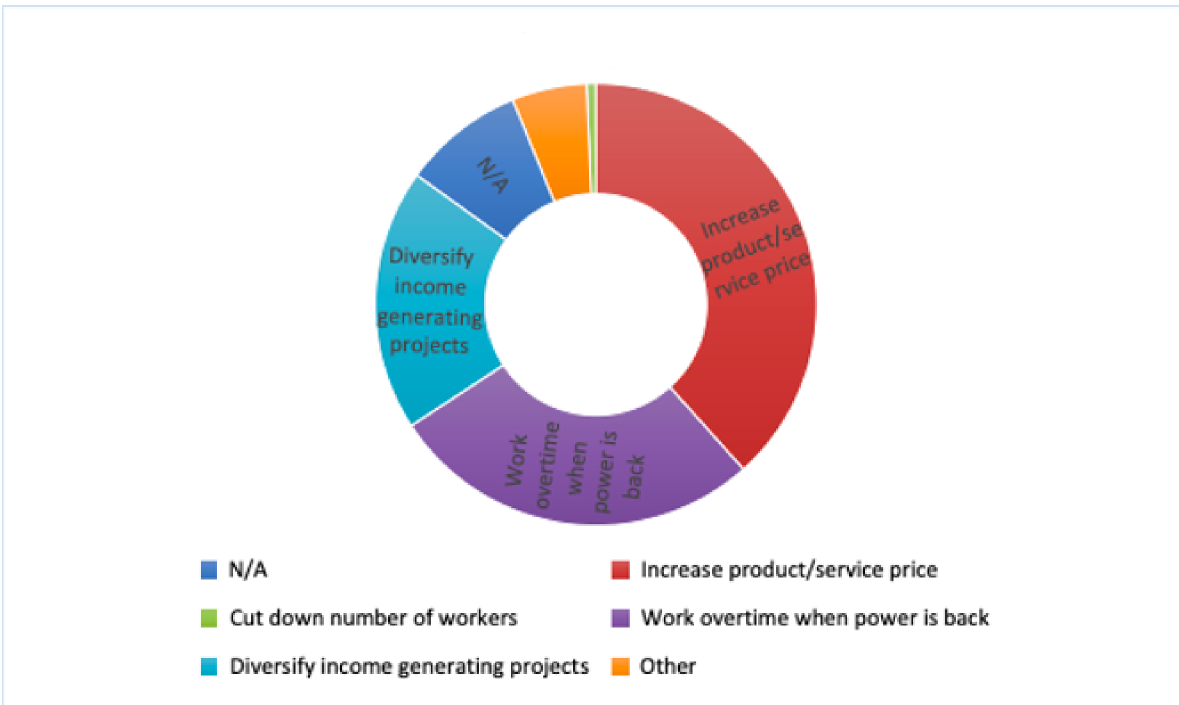

Figure 4.5.7 Measures taken to adapt to income loss
Source: Field survey (2018)

Electricity cuts impacted business operations in other ways besides productivity. Most businesses' customer bases were affected due to many disgruntled customers as illustrated by Figure 4.5.8. Of great concern was failing to meet set targets, as electricity cuts affected productivity. Many products were also spoiled or damaged, especially for clients who used electricity for refrigeration.

Figure 4.5.8 Challenges during load shedding
Source: Field survey (2018)

Respondents gave various reasons that they perceived to be behind the electricity cuts highlighted in Figure 4.5.9. The bulk of them were not oblivious to the economic challenges the country has been facing. However, a lot of blame was also placed on ZESA and maintenance challenges. The respondents also acknowledged the country's debt to ESKOM, the power utility that provides electricity to Zimbabwe from South Africa.

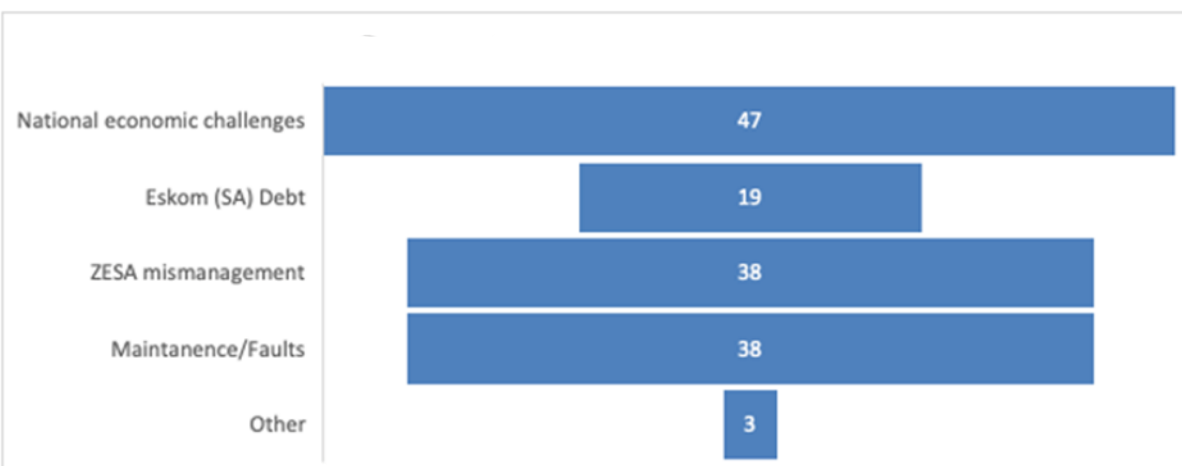

Figure 4.5.9 Reasons behind load shedding
Source: Field survey (2018)

Authorities posed challenges for people in informal businesses, with 24.7% of the businesses having faced problems from authorities, mainly council or national police. A few also had run ins with health inspectors. The problems faced mainly involved product raids, noise complaints and fines for operating without permits. Financial assistance from government was largely expressed as a need for informal businesses as shown in Figure 4.5.10. Training, market access and workspace are also of great importance as they would potentially make informal businesses more visible and improve returns.

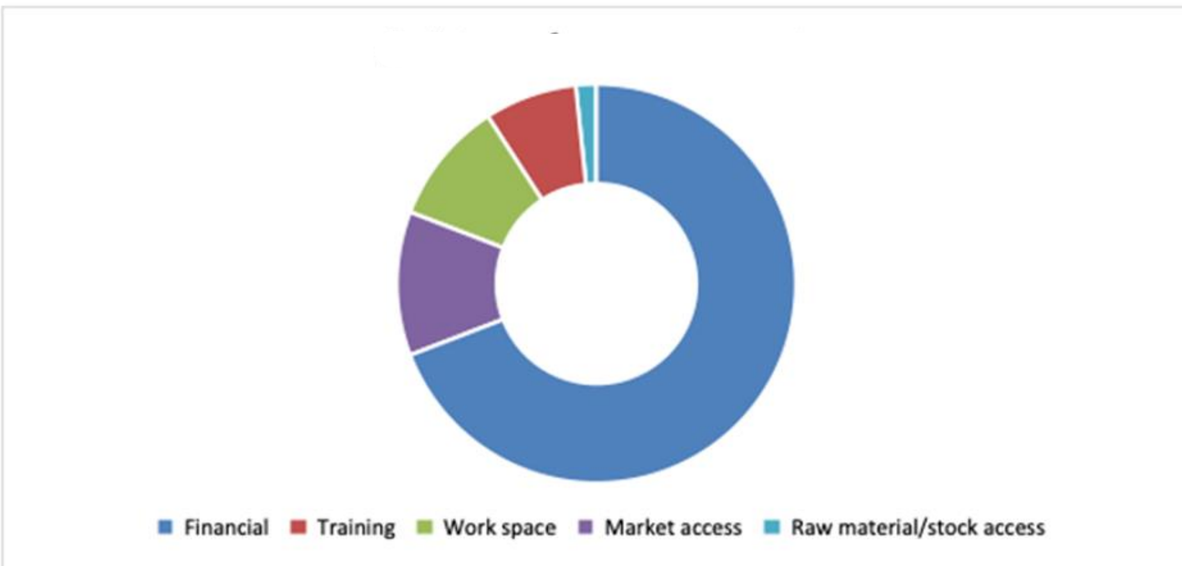

Figure 4.5.10 Type of assistance from government by home based informal businesses
Source: Field survey (2018)

4.6 The Role of Institutions and Policy Makers in Urban Livelihood Adaptation and Resilience to a Climate Change-Water-Energy Nexus

4.6.1 The role of government.

Government plays a leading role in addressing the climate change-water-energy nexus and its impacts on urban livelihoods. It provides financial, legislative and institutional direction for various sectors. Government's overarching roles are explained in table 4.6.1 below

Table 4.6.1 The role of government in climate change, water resource management, energy and urban livelihoods22

Category representing recurring responses	Description of responses
Financial	In all sectors government provides financial support as it engages in capacity building in the various areas. However, government fails to completely fulfil this role as it continually faces economic challenges. For example, the chief hydrologist in the Hydrology Department, in the then Ministry of Environment, Water and Climate mentioned that; *the country has a history of dam building and has the greatest number of dams in Africa, together with South Africa. However, development of infrastructure to access the water has remained a challenge* (Interview, 2018). Government facilitates infrastructural development and provision of affordable and reliable energy. It increased installed capacity of electricity for Zimbabwe when Kariba hydropower was expanded to boost installed capacity to 1050MW in 2018. Future expansions include the Batoka Hydropower project. It also keeps electricity affordable as mentioned by ZESA. It had a fixed tariff of US0.09/kWh for domestic consumers at the time of the interview in 2018. The tariff is blended since it is made up of tariffs from

different energy sources. ZESA was importing between 10 and 12 cents per kWh.

In the informal sector, financial assistance is usually afforded with loan repayment plans. Although informal businesses prefer loans with no stringent rules, government stated that loans must be paid back to get assistance. The director of SMEs went on to say, "*Government cannot help people that want funds for free. That attitude is how they exclude themselves from business financing. They should be willing to take risks that are involved with starting a business, and training for the business they want to engage in.*" The director also pointed out that government does not have the capacity to assist informal businesses like first world nations with capital, highlighting the economic challenges the country faces.

Legislative	Government drew up the National Climate Response Strategy (NCRS), National Climate policy (NCP), together with the water response strategy to address climate change and water resource management in Zimbabwe. In addition to these the Water Act and Water policy were crafted to ensure sustainable use of water resources. These are guided by the principles of the Institute of Water Resources (IWR). The Zambezi River Authority (ZRA) is a bi-national statutory body, jointly and equally owned by the governments of Zambia and Zimbabwe. It came about through acts of parliament in 1987, after dissolution of the Central African Power Cooperation (CAPCO). The 2001 Electricity Act spells out how the electricity industry is structured.

	Government creates laws like an SME act. They craft policies that create an enabling environment, conducive for people to improve their businesses, but it is wholly dependent on the extent of individual efforts.
Institutional Direction	ZINWA monitors all water bodies in the country and has a leading role in the National Water Resources Master Plan (NWRMP), with field experts to model future predictions in water resources funded by the World Bank. Zimbabwe's NCCRS is the country's response to climate change. There is also the National Climate Policy (NCP) to stipulate and regulate climate change related issues. The mandate of ZRA is to run the Kariba complex from Kazangula to Kanyemba as directed by the act of parliament between Zimbabwe and Zambia. ZESA generates electricity through the Zimbabwe Power Company (ZPC) and transmits and distributes through the Zimbabwe Electricity Transmission and Distribution Company (ZETDC). ZESA distribution is still government owned.
Enabling Environment	Government regulates the price of electricity, keeping to subsidized for domestic use. Electricity price regulation. Creates enabling environment for SMEs. Government assists the informal sector indirectly by providing decent infrastructure, roads and events like the Trade Fair to improve networking.

4.6.2 Climate change and water resources

Interviews with the then Ministry of Environment, Water and Climate, the MSD and ZINWA gave insights into the climate change and water resource use landscape in Zimbabwe. The responses are represented in Table 4.6.2 below using content analysis.

Table 4.6.2 Institutional role in climate change and water resource management

Category representing recurring responses	Description of responses
Monitoring and information sharing	All respondents of this sector are involved in record keeping. The MSD records all climatic data in the country. This is shared regionally through the Southern African Regional Climate Outlook Forum (SARCOF) and the Meteorological Association of Southern Africa (MASA) which is coordinated by SADC. Locally, the MSD of Zimbabwe annually convenes a National Climate Outlook Forum (NACOF), where the seasonal rainfall forecast for the upcoming rainfall season is presented to national stakeholders. ZINWA monitors all river systems in the seven catchments of the country. They have a network of gauging stations where they monitor river flow data. The same climatic and hydrological data from MSD and ZINWA respectively, was afforded to the researcher to look at long term temperature, precipitation and runoff data in the Kariba sub-basin. The Hydrology Department in the Ministry of Environment, Water and Climate is mainly concerned with surface water hydrology and monitors river flows and dam capacities. Water management is based on hydrological boundaries. Given the transboundary nature of many rivers, including

the Zambezi, data sharing occurs regularly between member states through bodies like the SADC Protocol on Shared Watercourses. It is the reference for all agreements between states that share transboundary water resources like rivers in Southern Africa. Others include the ZAMCOM agreement between Zimbabwe and the eight other riparian states that share the Zambezi River. The ZAMCOM agreement also stipulates procedures for developmental work that affects the Zambezi River, which includes notice periods and procedures on how to respond. The Joint Operations Technical Committee (JOTC) is another body that involves the operators of infrastructure like dams. In addition, the revised SADC Protocol on Shared.

Climate change perceptions and hydroclimatic patterns	Climate change was perceived by all institutions in water resource management and climate change and mentioned temperature and rainfall to be the climatic factors highly impacted. These are forecasted to continue to change. They acknowledged the risk on hydroelectric power due to drought, potentially impacting energy security for Zimbabwe. ZINWA's senior hydrologist highlighted that; *water resources are affected by temperature, rainfall, evaporation and wind. This results in decline in runoff (amount of discharge), increase in frequency of peak flows mainly associated with flooding and increase in low flows attributed to drought events* (Interview, 2018). He went on to mention the catchment areas with decreasing trends in flows. These were Runde, Mzingwane and Gwayi catchments. He also indicated that; *trends on the Zambezi were tricky because the Zambezi is volatile with peaks and dips* (Interview, 2018). The chief hydrologist in the Hydrology Department in the Ministry of Environment,

Water and Climate shared the same sentiments as ZINWA. He went on to say; *the impacts of climate change on water resources are very noticeable in the frequency of extreme events such as floods and droughts, which affect the availability of water resources. These extreme events have affected water bodies by breaching dams and other related infrastructure. Reallocation of permits and water rationing have, in some instances, been implemented due to droughts. Water levels in dams have also dropped (*Interview 2018). However, at the time of the interviews, the country's dams were 85% full, with the Zambezi River recording one of its highest river flows on record.

Sustainable use of resources

The principles of the Institute of Water Resources (IWR), together with the Water Act and water policy ensure sustainable use of water resources. The chief hydrologist outlined that water resource management in Zimbabwe is divided on a catchment basis. Each catchment, according to the Water Act, must produce a river system outline plan that is in view of climate change because of its potential impacts on water resources. However, the NWRMP would bring the catchments together, mapping a cohesive way forward in water resource management.

The Hydrology Department highlighted that Zimbabwe is predicted to be water scarce in the next 20 to 30 years, mainly due to issues of pollution and siltation of water bodies. The chief hydrologist indicated that; *desiltation of water bodies should take precedence over climate change issues and should be attended to, to create more space and avert flooding downstream. Dams are used for flood control and, with increase in extreme flooding events, they become useless if silted. Degradation of catchments and poor*

	agricultural practices are also a challenge (Interview, 2018). The Ministry has started desiltation programs but is limited by resources.
Regulation and compliance	ZINWA pointed out compliance and enforcing regulations as a challenge because people abstract water illegally, without water permits. An example given was the polluter pays principle which is difficult to enforce as some rivers or water bodies are used by multiple stakeholders. The water sector looks to the NCP to take care of the regulation and enforcement of climate change related laws. A priority system is used for competing water needs. Through an Urban, Industrial and Mining (UIM) system, domestic needs take precedence over agriculture and industry when allocating water.

The Southern African Development Cooperation appears to be the centre of coordination when it comes to water resource management, as presented in Table 4.6.2. Local authorities oversee monitoring climatic and hydrological data and share this through regional bodies like SARCOF for meteorological data, the revised SADC Protocol on Shared Watercourses, ZAMCOM and JOTC for hydrological data. Regional bodies help improve resource sharing in a coordinated manner, given the transboundary nature of water resources. This suggests that institutions play a monitoring and regulatory role of water resources. The consensus is that there has been a shift in hydrological and climatic variability, with an increase in occurrences and frequency of extreme weather events. However, long term trends in Zimbabwe are seldom processed and analysed although raw data is available and long-term trends can be evaluated. The NWRMP, together with the Water Act, takes care of the sustainable use of water resources in Zimbabwe. Institutions also pave the way by playing a strategic role in mapping the way forward in response to climate change and sustainable use of resources in Zimbabwe. Regulation of water resources is still a challenge and stakeholders are hopeful that the NCP will improve regulation and compliance issues. The country uses a UIM system when allocating water.

4.6.3 Energy

Interviews with the Ministry of Energy and Power Development, ZESA and the ZRA gave insights into energy structure and security in Zimbabwe. Using content analysis, the responses are represented in Table 4.6.3 below.

Table 4.6.3 Institutional involvement in energy security24

Category representing recurring responses	**Description of responses**
Operation and energy development	The energy sector is regarded a national security matter, with its structure of electricity determined by the Electricity Act of 2001. The Power Development Department in the Ministry of Energy and Power Development facilitates the development of power infrastructure and provide safe, adequate, reliable and cost-effective electricity. ZESA is in the electricity business, ranging from generation through the ZPC, to transmission and distribution through the Zimbabwe Electricity Transmission and Distribution Company (ZETDC). ZESA distribution is still government owned. It owns two companies (capacities) which manage its operations, PowerTel Communications (Private) Limited for data, and ZESA Enterprises (ZENT) to support its business. ZRA was formed in 1987 and one of the key purposes of ZRA is to manage the Kariba Dam complex and to develop hydroelectric power stations along the Zambezi River which

is between Zambia and Zimbabwe. Their mandate only runs between Kazungula and Kanyemba on the Zambezi River. ZESA had installed capacity in Zimbabwe at 1 950 MW. However, installed capacity equals a total of 2 220MW, according to the Power Development Department, with the installed capacities of stations as below:

Kariba Hydro Power Station – 1 050MW
Hwange Thermal Power Station - 920MW
Bulawayo Small Thermal Power Station - 90MW
Munyati Small Thermal Power Station - 100MW
Harare Small Thermal Power Station - 60MW.

Installed capacity meeting demand

There is a difference between installed capacity and available capacity. The power stations were designed to supply a total of 2200MW. However, due to obsolete equipment, low lake levels and sometimes fuel shortages, the stations can no longer perform at their peak. Power supply in the country is currently being augmented by imports from neighbouring utilities. The Kariba Power Station only uses all eight units during peak demand periods to adhere to the water allocations by the ZRA.

According to ZESA, *currently, Kariba Hydro Power Station is the main contributor since it has the highest installed capacity of 1050 MW. It is also relatively reliable since it is not affected by frequent equipment breakdowns. However, it is not base load; it is a peaking station, ramped up during peak demand and slowed down when demand goes down* (Interview 2018). ZESA points out that; thermal *as the base load, but Kariba Hydropower has been used as base load due to aged and unreliable thermal stations* (Interview, 2018).

	ZESA believes they are meeting demand, but that is because of a depressed economic environment. Hence, they consider it suppressed demand and not the true demand.
Tariffs and cost of electricity and Independent Power Producers (IPPs)	As a result of the Electricity Act, ZESA only has a monopoly on transmission and distribution, with generation open to anyone and government regulating pricing. The utility used a fixed tariff of US0.09/kWh for domestic consumers at the time of the interview in April 2018. The tariff is blended since it is made up of tariffs from different energy sources. ZESA was importing between 10 and 12 cents per kWh. Independent Power Producers (IPPs) had to produce electricity and price at 9.86 per kw because they feed into the grid and must still make a profit. This has proven challenging for IPPs which calls for an independent regulator as the price has been kept this low since 2011. ZESA introduced prepaid metres in the country. According to ZESA, *Prepaid metres are a double edge sword. They guarantee revenue, but they also make consumers aware of usage. While prepaid metres guarantee revenue inflow, they also make DSM occur more often and put a direct relationship between cost and usage* (Interview, 2018)
Hydropower and Kariba Hydropower Station	Kariba Hydropower station is the main hydropower station. Two units were commissioned in 2018, boosting capacity from 750MW to 1 050MW. There are also mini-hydro power stations operated by IPPs. The Power Development Department indicated that; *the largest IPP currently has a total of 25 MW. These are seasonal suppliers since they operate on run of river* (Interview, 2018). The ZRA allocates

water from Lake Kariba for hydropower generation to the two utilities, ZESA (ZPC) in Zimbabwe and ZESCO in Zambia, in October annually. The allocation is done for the sustainable management of the reservoir and is not related to demand for electricity. The ZRA relies on weather forecasts performed by SARCOF to inform decisions regarding water allocation. ZRA mentioned that; *Kariba Dam is one of the leading structures in terms of maintenance in the world* (Interview, 2018), squashing claims that it is falling apart.

Climate change and hydropower

The major challenge indicated of late is periodic low lake levels at Kariba. Each time the country experiences drought resulting in low rainfalls, hydro power plants are affected. Reference was made to the La Nina induced drought of 2015, which caused the lake level at Kariba Dam to deteriorate drastically. Consequently, the ZRA had to give revised maximum water allocations that each utility (ZPC and ZESCO) could consume annually. This measure was put in place to control water used for generation since the dam was a resource shared by two countries. That year, ZPC generated at an average of 480MW. Furthermore, ZESA mentioned that; *around 2015/2016, output at Kariba was somewhere between 285MW and 265MW, even though the plant could give 750MW […] Kariba generating less and the thermal power station being old, ZESA had to rely on imports to meet demand. The situation was so dire that the ZPC sometimes had to bank water and use it during peak periods. The SAPP region had no capacity, including South Africa and Botswana who were also trying to increase capacity by building Madupe and Morupule power stations respectively. Hence, massive power cuts were experienced in the country*.

	ZESA suggests that hydropower output has been constant for a very long time, but every time there are droughts, reductions in generation are experienced, as seen in 1992 and 2015/2016. In May 2018, water levels were impressive with dam levels at 83%. ZESA indicated that; *Kariba's catchment area is in the Barotse plains in Zambia and has two rainfall patterns, with the peak period of inflows into Kariba Dam experienced in June/July* (Interview, 2018). The ZRA went on further to say; *the ZRB is unique in that it behaves like a pendulum, and its climate and hydrology can go either way [...] 2015 as challenging but unprecedented because it was a very dry year. In the 2016 season, lake levels improved and water allocation for utilities has increased in the last three years.* The head of public relations at the ZRA is of the view that; *climate is cyclic with years of droughts which do not affect the function of the dam long term* (Interview, 2018).
Energy security and expansion	ZESA believed the region to be energy secure in 2018, largely because many Southern African countries had increased capacity or were in the process of doing so. The SAPP allowed for trade in electricity and any deficits Zimbabwe experienced could be imported. Upstream of Kariba, about 54 km down from the Victoria Falls, the Batoka Hydropower station is in the pipeline and is within the area of responsibility of ZRA as it is located between Kazungula and Kanyemba. The project is bilateral between Zimbabwe and Zambia and will generate 1 200MW for Zimbabwe. Even though climate change is a key risk to the project, the benefits outweigh the risk.

Solar projects are on the cards, with an expected total of 300MW. ZESA expressed that; *utilities are very sluggish in investing in solar energy as luminance is low during peak demand periods and not always reliable when there is cloud cover. However, the cost per megawatt of solar energy and of the equipment has plummeted (*Interview, 2018). ZESA mentioned many expansion projects, largely funded by banks in China.

The Hwange Power Station expansion project is also expected to commence soon, producing an additional 600MW. The refurbishment and expansion of Hwange Thermal Coal Power Station will happen in stages. Stage One will produce the former units at 120MW, Stage Two involves 220MW and Stage Three will bring in 300MW. It will then take its place as the baseload. The cost of generation can be diluted by Kariba

ZESA was working hand-in-hand with Secunda Power Station in South Africa to potentially set up a diesel 200MW thermal station in Mutare.

ZESA points out that; *system development plans look at least cost and that is how future energy projects are determined. They favour hydropower because of lower costs, for instance, generation at Kariba costs two cents per kWh compared to six cents per kWh at Hwange Power Station. The other thermal power stations in Harare and Bulawayo cost anything between seven and ten cents per kWh or even 12 cents per kWh. Hence, Batoka is considered a viable option […] country sits on 15 000 years supply of coal and there is no appetite to finance dirty production. Although there are new, cleaner methods, they are capital intensive*.

Water remains a challenge, especially for smaller thermal stations like Harare and Bulawayo as there are competing

	water needs in cities. Hwange Power Station drew a line from the Zambezi to mitigate the same problem. Hence, if the country is water scarce, thermal sources of energy are also potentially impacted by climate change.
Demand side management	As a utility, ZESA has five companies. ZENT is seen as the supporting arm of the business and is growing into technologies like solar geysers. ZESA highlighted that; *ZESA removes users from the grid but gets them back on the other side through ZENT.* They gave an example where; *Government removed tariffs on energy servers to try and lower costs. They rolled out free bulbs as a deliberate policy, but the net effect was that load was lowered by 180MW, creating virtual power by just putting in bulbs. People placed control systems that can switch geysers off in their house, which removed another 40MW. In addition, solar panels are duty free, thus encouraging use of alternatives.* However, ZESA believes their business is not DSM but Supply Side Management. They need to ensure that they are maximising shareholder value.

The management of electricity in Zimbabwe, from generation, transmission to distribution, is centred around ZESA, as represented in Table 4.6.3. Hence, ZESA has a leading role in the electricity business. IPPs can also generate electricity in Zimbabwe but are always challenged by pricing as ZESA and government regulate pricing. The country has a combination of energy mixes for electricity generation that mainly consist of thermal and hydropower. Thermal's reliability has diminished through the years due to obsolete and aged plants that are constantly down for maintenance. Refurbishment and expansion of some thermal stations is on the cards. Zimbabwe's base load is currently supported by hydropower, which was recently boosted to 1 050MW at Kariba Power Station, although Kariba is a peaking station. Management of the Kariba Complex rests on the ZRA. They are mandated to allocate water for generation for both Zimbabwe and Zambia from Kariba. They rely on forecasts by SARCOF highlighting how climate, hydrology and energy are connected.

Kariba is a single purpose dam, but national parks and municipalities have access to water from the dam. Low lake levels that impact generation are a challenge for the two countries that depend on Kariba. ZESA and the ZRA believe droughts are cyclic and will always impact electricity generation at Kariba. However, droughts are periodic, and the country can always rely on imports from the SAPP as most countries' capacities have improved. Expansion by building other plants that include Batoka and Hwange would take care of future deficits, especially in drought years. The retrofitting of many single purpose dams to generate electricity built in Zimbabwe is something government has considered. However, capital and funding remain a constraint. Water remains a challenge, even with thermal stations, as a number are built close to cities where competing water needs potentially affect allocation to power plants. Strategies to reduce pressure on the national grid using DSM practices have been implemented. ZENT is also in place to push that agenda. The push for renewables will largely include hydropower from Batoka. Solar projects are on the cards but ZESA is hesitant in investing hugely in solar. They are of the opinion that luminance is low during peak demand periods and hence cannot always be reliable and could not form the baseload for the country.

4.6.4 Informal sector

Interviews with the department of Medium and Small Enterprises under the Ministry of Industry and Commerce gave insights into the ministry's function in the informal sector of Zimbabwe. The responses, using content analysis, are represented in Table 4.6.4 below.

Table 4.6.4Stakeholder participation in informality

Category representing recurring responses	Description of responses
Criteria for selection and women in the informal sector	Government does not have selection criteria when assisting SMEs. They remain neutral and do not provide financial assistance based on gender as they view this as unfair. The director stated that they do not segregate between genders because they want to treat them equally. He went on to say questions will be asked regarding why government is assisting and separating by gender; *Some will say, 'You are trying to perpetuate a patriarchal environment, where you think you need to dictate to women and tell them what is good for them.' They will ask you; 'why you would divide us? Can't you just invite us as compatriots and we talk, we will sort ourselves on class and who we are'.* He pointed out that the majority of people with informal businesses that visit their offices are women. He added that many of them have become very articulate and professional, so it incenses them to be segregate on gender. He mentioned that when he attends to the issues of people in informal business, he attends to the issues of women without putting it out there that he is addressing women's concerns.
Formalising and registration of the informal sector	The director mentioned that informal businesses are difficult to identify by virtue of them being informal, so government is trying to formalise them. He added that; *businesses grow when they are formal*, [...] *Formalising creates decent jobs with social security, benefits and decent income. Government's plan*

is to get informal businesses out of informal spaces, into designated permanent spaces where they pay rates and become known. This is also meant to incentivise informal businesses operating at home to enter these spaces where the markets are better. Government wants to be positioned to influence that move (Interview, 2018).

There is no register of informal businesses, but government is working on creating such a register. Having such a data set can be constructive, navigating into the informal space and improving the assistance afforded to informal businesses. At the time of interview, the register had 18 000 members, but government believes the true number of people in the informal sector exceeds one million.

Government is working with local councils to design places for informal businesses. The director mentioned talks with the Central Bank of Zimbabwe (CBZ) and Harare City Council about developing an area between Coca Cola in Cripps Road and Chitungwiza Road, ten hectares in size. He mentioned that; *CBZ is building a place there to accommodate about 3 000 SMEs. The same was to be done in Glen View Area 8. Tenants will pay subsidised rates (half) for about four years. Those that have borrowed from banks will be charge less interest as an incentive for doing well and paying back* (Interview, 2018).

In addition, CBZ, Old Mutual and First Mutual, among others, would also be consulted to revamp Siyaso (informal market). They would improve roads and street lightning so that people can work 24 hours a day and to create a family-friendly environment. Government hopes this project would be completed within four to five years. *The idea is to bring in people that have capacity, bring the plans, build it and they can charge whatever they want to retrieve/recover their costs. Such a project would take council 20 years to complete because*

> *it is local government. Government can negotiate with council to offer the land at a lower price* (Interview, 2018)

The Medium and Small Enterprise Department largely creates an enabling environment for SMEs but is not an active player. There are no criteria used for selecting which businesses get assistance, including gender. Women appear to be the majority in informal business but are not directly assisted or recognised based on their gender. The department believes that by addressing the concerns of people in informal business, they have helped women in informal business as they form the majority. The department has been working on formalising the informal sector by creating a register. They have also been working on creating an enabling environment by proposing the development of workspaces and places of trade. The idea is to move people from operating at home and at stalls that do not grow their business. Once they operate in designated areas with large foot traffic, their businesses grow, and they become known and formalised. They have also targeted micro-financing firms for lower interest rates and long loan repayment plans for small businesses. However, it was pointed out that there are no free funds and beneficiaries have to pay back loans.

4.7 Conclusion

In summary, this chapter presents detailed results of data gathered from ZINWA, the MSD, the household survey, in-depth interviews and the World Bank website. The main focus was how a climate change-water-energy nexus impacts energy security and urban livelihoods. The findings of the study bring to light the historic hydroclimatic and hydropower generation trends and interactions observed in the Kariba sub-basin. The results show:

a) an increase in temperatures and a reduction in precipitation, runoff and hydropower generation,
b) a positive interaction between temperature, precipitation, runoff and hydropower output

c) a suggestion that the sub-basin is getting drier and warming, while generating less electricity.

The results also shed light on the characteristics of informal livelihoods and their challenges due to power outages. These results show:

a) informal businesses being practiced by all socio-economic groups with different strengths and weakness,
b) home-based informal business present with typical characteristics of informal businesses,
c) power outage impact on productivity and income of informal businesses,
d) ability to adapt due to energy insecurity has a bearing on income earned in informal businesses, and
e) the urban poor are more vulnerable to energy insecurity.

The results suggest that urban livelihoods are impacted by a climate change-water-energy nexus. The role of institutions is led by government, while implementation occurs at local level.

CHAPTER FIVE: DATA ANALYSIS AND DISCUSSION

5.1 Introduction

This chapter discusses the empirical findings of this research presented in the previous chapter. The purpose of this chapter is to interpret and describe the significance of the findings in relation to and in the context of study, while explaining any new understandings of the area of research. In essence, the chapter's discussions talk to the aims and objectives of the study. The first section discusses the hydroclimatic variability and hydropower generation in the Kariba sub-basin. The next section looks at how a climate change-water-energy nexus affects urban livelihoods. The last section looks at the role of institutions in urban livelihoods.

5.2 Climate Variability and Hydropower Generation in the Kariba Sub-Basin

5.2.1 Hydroclimatic and hydropower generation trends in the Kariba sub-basin

The Kariba sub-basin exhibits a warming trend for annual and seasonal maximum temperatures. However, only annual maximum temperatures show a significant warming trend at all sites. The warming trends match those observed in earlier studies of Southern Africa (New, Hulme and Jones, 2000; Hulme *et al.*, 2001; Tadross, Jack and Hewitson, 2005; New *et al.*, 2006; Christensen *et al.*, 2007; Engelbrecht, McGregor and Engelbrecht, 2009; Engelbrecht *et al.*, 2011; Engelbrecht, Engelbrecht and Dyson, 2013). This warming trend in annual and seasonal maximum temperatures is likely to continue as predictions for Southern Africa and the ZRB by other authors suggest a warming trend in annual temperatures and all seasons (Christensen *et al.*, 2007; James and Washington, 2013; IPCC, 2014c; Hamududu and Killingtveit, 2016). Christensen *et al.* (2007)'s prediction of the highly arid south and southwestern areas of the ZRB includes significant increases in temperature. The Kariba sub-basin is in that area, hence the projected increase in temperature will occur and the warming trend experienced will likely continue.

One unanticipated finding was that the minimum temperatures showed a decreasing trend annually and seasonally at all stations, except in the wet season in Kariba. However, the decreasing trend was only significant in Victoria Falls in the wet season. It is uncharacteristic of temperatures to drop especially in the wet season when it is the hottest season of the year. These trends contradict earlier findings by New *et al.* (2006) who observed an increase in minimum temperatures in Southern Africa. Furthermore, the increase in minimum temperatures was more rapid relative to the maximum temperatures. These findings would also not support the future trends observed by Christensen *et al.* (2007) and James and Washington (2013), who predict a general warming in all seasons. While Binga showed a significant decreasing trend in annual and seasonal temperatures, its accuracy remains questionable because it had a lot of missing data. Of interest is the remarkable drop in minimum temperatures in 2004 at all stations. Literature to explain other factors that may be the reason for such low readings in 2004 is scarce. This anomaly could have been an error is data capturing. The low readings may have influenced the decreasing trend observed, hence, these results on minimum temperature need to be interpreted with caution.

Annual precipitation patterns in the Kariba Basin, at all stations, matched the years of extreme weather events in the ZRB and Southern Africa observed by ZAMCOM (2015). The droughts of 1981/82, 86/87, 91/92, 94/95 and 2001/2003, and floods of 1999/2000, 2006/2007, among others, are evident and presented by increases or decreases in precipitation respectively, at all stations during those years. The region is clearly prone to and sensitive to extreme weather events. These extreme events are projected to continue to increase in Southern Africa and the ZRB due to climate change, as highlighted in literature (Mason and Joubert, 1997; Tadross *et al.*, 2005; New *et al.*, 2006; New *et al.*, 2006; IPCC, 2007a; Beilfuss, 2012; Engelbrecht *et al.,* 2013).

Moreover, tropical storm Chedza in 2014/2015 and, more recently, tropical cyclone Idai in 2019 ravished Southern Africa and had devastating effects in Malawi, Mozambique and Zimbabwe. They displaced and disconnected communities and destroyed infrastructure (ZAMCOM, 2015; WMO, 2020). Tumbare (2010) found that 30% of the 200 years of rainfall data in his study were drought years. These events have shown Southern Africa's vulnerability to extreme weather events. Climate change increases the frequency and intensity of these events. These trends grossly affect vulnerable populations whose adaptive capacity is low.

Precipitation in the Kariba sub-basin showed a decreasing trend annually and seasonally for all stations except the Victoria Falls wet season, where the trend was increasing. However, only the Kariba wet season showed a significant decreasing trend. These findings are in line with observations made by Hulme *et al.* (2001) and Niang *et al.* (2014). They observed decreasing precipitation in the 20th century, especially for the summer rains in the western parts of southern Africa, which is the location of the gauging stations under study. Decrease in precipitation negatively affects water availability in a region that already experiences high variability in water resources. It affects sectors that depend on water resources which include the agriculture and the energy sector. These decreasing trends are likely to continue in the basin as projections for Southern Africa and Zimbabwe by Christensen *et al.* (2007), Shongwe *et al.* (2009), Engelbrecht *et al.* (2011) and the IPCC (2007a) indicate decrease in rainfall, with drier summers projected over Zimbabwe. Research has also predicted that the ZRB will experience a decrease in annual and seasonal rainfall (IPCC, 2007a; Shongwe *et al.*, 2009; Beilfuss, 2012). This outlook suggests a worsening drying trend in the region that already faces variable precipitation patterns, challenging water security.

Long-term runoff data shows most rivers peaking around February, during the wet season. This is around the time rainfall is at its peak. However, the Zambezi peaks at a different time, between April and May. The independence of the

Zambezi River suggests multiple or other factors that affect its flow. The source of the Zambezi is from the Kalene Hills, passing through eight countries, with various tributaries along the way (Tumbare, 2010; World Bank, 2010; ZAMCOM, 2015). The transboundary nature of the river likely subjects it to the multiple rainfall patterns experienced in the nations it flows through. Hence, it peaks at a different time to the other rivers that are predominantly located in Zimbabwe alone. Furthermore, the World Bank (2010) mentions a lag of about four months in peak rainfall experiences in the Kariba sub-basin, with the upper region experiencing it in December/January then, in April and May, peak flooding at Victoria Falls follows. Victoria Falls was the site of the Zambezi River gauging station, which explains the matching observations made in the study.

The annual river patterns of the Kariba sub-basin showed variable peaks and dips, speaking to the variability of the basin as mentioned by Davies (1989), Cai and Cowan (2008) and Tumbare (2010). These were consistent with extreme weather events experienced in the region. The drought of 1981/82 is visible, with the Zambezi's river flow decreasing around that period. Sanyati, Gwayi and Shangani rivers recorded no flow in the same period. In addition, these were highlighted as years of extreme weather events by ZAMCOM (2015). This highlights the severity of the drought in that region of the sub-basin and sensitivity of the sub-basin to extreme climatic events. Annual river runoff of all the rivers showed a decreasing trend, except for the Zambezi River, which had an increasing trend. However, only Sanyati River had a significant trend and carries a larger volume of water than Gwayi and Shangani. The Kariba sub-basin is the driest in the ZRB, hence a decreasing trend in its river flow is not surprising. Time series data in the study showed that Gwayi and Shangani experience much lower volumes of water, with periods where no water flows through the rivers, which possibly contributes to the insignificant decreasing trend when compared to Sanyati River.

The decrease in river flow observed in the Kariba sub-basin threatens water resource use for Zimbabwe and the populations that depend on it. Predictions of continued drying and warming will adversely affect the already semi-arid Kariba sub-basin. By 2050, the IPCC (2001) predicts a decrease in annual river flow of about 26-40%, while Hamududu and Killingtveit (2016) foresee a 14-26% decrease in river flow in the basin by the end of the century. Studies of the ZRB river flows have been limited to the entire sub-basin, with little focus on predictive studies that focus on sub-basin levels. The semi–arid regions where the Kariba sub-basin sits will probably experience water stresses in the future if the observed trends in climate and hydrology continue. The IPCC (2007a) and Beilfuss (2012) share the same opinion on the sub-basin.

A decreasing trend in hydropower generation output was observed for Zimbabwe, which tied in with climatic trends in the region. The pattern shows a significant drop in hydropower contribution to the national grid around 1984/85, which ties in with the introduction of Hwange Power Station which added to the installed capacity for Zimbabwe, reducing dependence on hydropower. However, the dip in hydropower generation in 1981/82 ,1991/92 and other drought years in the region is visible. Droughts reduce runoff, followed by reduced reservoir storage capacity, resulting in reduced hydropower generation. The Kariba Dam is evidently sensitive to climate variability, hence, when dam capacity is drastically reduced in the dry and warm years, hydropower generation is reduced. Low dam levels in the 1992/93, 2015/16, and 2019/2020 seasons, threatening the shutdown of Kariba Hydropower Station, were also observed by the ZRA (2016; 2019) and NASA (2016; 2019). This above situation threatens the country's energy security which heavily depends on hydropower. According to the Ministry of Power and Energy Development as well as ZESA, hydropower has an installed capacity of 1 050MW, mainly from Kariba, with the country's total installed capacity sitting at between 1 950MW - 2 220MW. They went on to state that the thermal power stations in Zimbabwe are old and obsolete and are not as reliable as Kariba, hence, they perform well below capacity. Kariba has therefore been used as base load, even though it is regarded as a peaking station in Zimbabwe. This again is due to thermal power stations being unreliable and constantly breaking down. This indicates that hydropower makes up about 50%

of installed capacity and its electricity contribution to the national grid is even higher in Zimbabwe. Similar sentiments have been expressed in literature by Kaseke (2013) and Afshar (2018), who stated that hydropower from Kariba Power Station contributes significantly to the energy mix in Zimbabwe as other power stations, mainly thermal, are old and constantly under repair. Its contribution to the national grid has varied over the years, depending on the contribution of other sources, which are mainly thermal.

The observation made by the study of a general warming and drying trend, together with decrease in river flows in the arid regions of the ZRB, will likely continue, with a negative impact on hydropower generation at Kariba. There is a growing consensus among researchers who predict a decrease in hydropower generation in the ZRB (Yamba *et al.*, 2011; Fant *et al.*, 2015; Conway *et al.*, 2017b; Spalding-Fecher *et al.*, 2017). Kariba Dam has one of the worst outlooks as it is in the semi-arid Kariba sub-basin. The study has shown the threat of climate change in the Kariba sub-basin where a warm, dry climate and reduction of water resources has been occurring. This has threatened availability of water resources in the region for various sectors and poses a threat to energy security for Zimbabwe.

5.2.2 Relationships between climate, hydrology and hydropower

While hydroclimatic and hydropower generation trends gave insights into historic patterns in the Kariba sub-basin, their relationships affect availability of water resources and hydropower output in the region and are therefore worth exploring. Temperature and precipitation had a linear relationship with runoff, at Victoria Falls, highlighting that climatic factors affect runoff, which subsequently affects reservoir storage capacities. Tang *et al.* (2013) also established a relationship between climatic factors and runoff in the Yellow River in Asia, with a decrease in precipitation resulting in a decrease in runoff. This kind of relationship was found in the study at Victoria Falls. Cai and Cowan (2008) speak to the highly arid nature of the ZRB. They go on to point out that small changes in annual precipitation can have a large impact on annual river flows. The findings of the current study corroborate those of Cai and Cowan (2008), where temperature and precipitation impact runoff. The findings are also in agreement with characteristics of the Kariba sub-basin as highlighted by Davies (1986), World Bank (2010) and Beilfuss, (2012). They allude to the seasonality of runoff and river discharges in the Kariba sub-basin as it tends to respond to rainfall events. Muchuru *et al.* (2014) indicates rainfall to be the main driver of inflows into the Kariba catchment. This highlights the strength of the relationship between precipitation and runoff in the sub-basin. Furthermore, the runoff measured at Victoria Falls, determines the water available in Kariba Dam and the water allocations that are given to power generating utilities at Kariba Power Station, as indicated by the ZRA and ZESA during interviews. This suggests Kariba's dam capacity to be sensitive to climatic changes, therefore influencing the water available for electricity generation.

Successful electricity generation from hydropower is strongly influenced by river flows. Runoff had a linear relationship with hydropower at Victoria Falls. Runoff explained 27% of changes seen in hydropower. Present findings are in accordance with assertions in literature that acknowledge the role runoff plays in successful hydropower generation (WCD, 2000; Schulze *et al.*, 2005; Mukheibir, 2007; Blackshear *et al.,* 2011; IEA, 2012; Cisneros *et al.,* 2014). The relationship between runoff and hydropower highlights the dependence of energy on water. This was also alluded to by ZESA and ZINWA, as they noted that the runoff measured at Victoria Falls (the Zambezi gauging station used in the current study) influences water allocations for generation at Kariba Hydropower Station. This relationship has a bearing on energy security for Zimbabwe, challenging successful hydropower generation in a changing climate.

Together, temperature, precipitation and runoff explained 33% of the changes seen in hydropower output. This highlights the role hydroclimatic variables play in hydropower generation. Hydroclimatic variables have been found to be the major determinants among other variables that impact hydropower generation.

The impacts of climate change on these hydroclimatic variables hinders successful hydropower generation as other studies have indicated (WCD, 2000; Schulze *et al.*, 2005; Mukheibir, 2007; Blackshear *et al.,* 2011; IEA, 2012; Cisneros *et al.,* 2014). Runoff was an independent predictor of hydropower in the study. This emphasises the direct impact that runoff has on hydropower output as previously discussed. Threats from a drying and warming climate, with reduction in river flows, will impact hydropower generation at Kariba and the ZRB. Similar sentiments were shared by Yamba *et al.* (2011), who indicated that dry years will result in a gradual decrease in hydropower generation in the ZRB. Spalding-Fecher *et al.* (2017) also made reference to Kariba's sensitivity to climatic changes and how a drying climate would reduce hydropower output in the ZRB. Extreme weather events are said to increase in the ZRB (Tadross *et al.,* 2005, New *et al.,* 2006, IPCC, 2007a). These extremities, like drought or below normal rains, reduce power generating capacities of hydropower stations through reduced runoff. These have historically impacted hydropower generation in the region, especially at Kariba Dam in 1992/93, 2015/16 and 2019/20, resulting in massive power cuts in Zimbabwe and Zambia. This has devasting effects on sectors that heavily depend on electricity, affecting economic growth and livelihoods. Conclusively, the results in the Kariba sub-basin mainly point out that the hydrological cycle determines the availability of water resources that hydropower generation directly depends on. Therefore, hydropower success is attributed to the excess water that turns into runoff. This excess water results from precipitation and evaporation, which are determined by temperature, among other factors. Therefore, a climate change-water-energy nexus exists in the Kariba sub-basin. It impacts on hydropower generation and energy security for Zimbabwe.

5.3 Urban Livelihoods and Energy Insecurity

5.3.1 Characteristics of informal businesses in Zimbabwe

a) Who are the people in informal businesses?

Home-based informal work in Zimbabwe is run by educated women who are mainly household heads. They have basic educational skills, which aid them in running home-based informal businesses as a means of survival. This speaks to the literacy rate in the country, which is still high. These findings contrast with experiences highlighted by Chirisa (2013). The women found in informal trade in his study were not educated. Some had gone up to Ordinary Level, though most had not passed that level of education. The various types of informal trade may have a bearing on these differences. Chirisa (2013) surveyed women in informal trade that included vending and hawking of retail goods, which did not require any skills. This contrasts with the current study which involved businesses that required electricity for production or service. This would, in some instances, require training or education to some level. In addition, the differences in education level between the Chirisa (2013) survey and the current survey can be explained by Gindling and Newhouse (2014). They suggest that own-account workers fall anywhere between highly educated and least educated, which was seen in the different findings, with employers being the most educated.

Households surveyed were averaged sized with equal distribution of men and women per household suggesting absence of overcrowding across the board. The informal businesses that the women carried out were their main form of employment, though a considerable number held or kept full time jobs. The informal business of those with full time jobs became an extra source of income. Hence, the informal sector is flexible and allows for diversification of livelihood strategies, with similar sentiments shared by Chirisa (2009) and Njaya (2015). Salaries and informal businesses made up the sources of income for most households. This finding highlights the role that multiple incomes play in supporting households, as cities like Harare are largely commoditised and expensive. This also shows the informal sector as a source of job creation and income generation for the urban population, with evidence of this also stated by other authors (Karekezi and Majoro, 2002; Haan and Maclean, 2006; Schneider *et al.*, 2010; Chirisa, 2013; Chen, 2016). Women usually venture into informal trade as a survivalist economic activity to support the household income. Similar views are expressed by Stuart *et al.* (2018), who also support the role informal businesses play in income generation.

Most households in the survey earned a decent amount of between $501-1000 as their total household income, indicating the contribution of informal home-based work in supporting household income. Given the average size of the surveyed households, this amount allows for a fairly comfortable life. The lowest tier of total household earnings was in the HDRAs. This would be expected of HDRAs as assumptions were that low income earning households live there. Some high-income earners still chose to live in HDRAs where accommodation and rates are much cheaper. The highest earnings were also present in the HDRAs, where household income exceeded $5 000 and supports a household substantially as other expenses are reduced in these areas compared to MDRAs and LDRAs. These observations indicate the informal sector's contributions to income and employment of urban populations. Similar remarks were made by Schneider *et al.* (2010) and Chen (2001; 2016) about the informal sector. Karekezi and Majoro (2002), Charmes (2012), Chirisa (2013) and Brown and McGranahan (2016) added on by acknowledging that the informal sector is one of the largest employers on the continent and a source of livelihood.

Remittances received by households in LDRAs only could potentially show the differences in family success in the various residential areas. Those in LDRAs have relatives that have travelled abroad, and work elsewhere, and hence have the capacity to send money back to family. Most respondents in LDRAs also had access to credit, purchased their own homes and could afford the luxury of have two or more cars per household compared to the other residential areas. Their asset base was the strongest. The combination of these findings provides some support for the conceptual premise that households in the LDRAs were wealthier and the HDRAs households were least wealthy with a low asset.

b) Structure and type of informal businesses

Most businesses practiced by women in home-based informal business were chosen because of ease of doing business at home. Poultry and tailoring are examples of such businesses. The home made it easy and convenient to practice these businesses as infrastructure and space could easily be created and put together, with electricity was readily available. This is in line with Chen *et al.* (2016)'s findings which emphasised the home as an essential resource for home-based informal work. However, Eapen (2001) and Fapohunda (2012) believe that women find themselves in the informal sector because they are unskilled or because social and cultural barriers dictate their role in the home as homemakers. Carr *et al.* (2000) adds on by stating that women combine their home-based informal work with their domestic roles to enable them to earn an income. Surprisingly, the male dominated type of businesses like welding and carpentry were also practised by women. Women usually ran the administrative part of such businesses and employed men to do the work. This finding provides an alternative view on the type of informal work women are involved in, as they are also present in male dominated spaces. Similar findings were expressed by the ILO (2017), where women were involved in male dominated informal work. In contrast to the current study findings, women in the ILO study performed the tasks themselves, from welding, carpentry and mining to stone quarrying, and did not only run the administrative part of the informal work. This could be a reflection on the dire situation in the country that has forced women to venture in male dominated trades. It could also be an indication of how empowered women have become in Zimbabwe, as gender roles have been modified.

The findings of the study suggest that home-based informal work empowered women as it made it easier for most women to own their own businesses entirely. This agrees with Charmes (2012), who points out that women in informal businesses are usually self-employed. This view is also supported by Chen *et al.* (2016). Most businesses were own-account enterprises, a characteristic thought to be true of most of the workforce in developing countries, according to Stuart *et al.* (2018). The authors go on to suggest that own-account workers and contributing family workers make up about three quarters of workers in developing countries. However, in the current study, an association between type of enterprise and residential area shows that in MRDAs and HDRAs, women were self-employed, but in LDRAs, women chose to employ people to help run their businesses and not have family members working in the informal business. This could be because LDRAs families are usually affluent and wealthier and would therefore rather run their businesses on their own or employ people to do so than involve their families for labour.

Informal businesses have been there for a long time and the sector continues to grow; hence, businesses were as young as under a year or as old as 20 years. The sizes of the home-based informal businesses remained small, with businesses employing up to six people with the average number of people employed just under two. Therefore, the study showed that the informal sector offers job creation for many residents of Harare, with similar findings expressed by other researchers. Benjamin and Mbaye (2014), for example, indicated that 84% of employed women belong to the informal sector. Chen (2001;2016) adds on by stating that in the 1900s, 93% of new jobs in sub-Saharan Africa were in the informal sector, highlighting the role of the informal sector in job creation. Furthermore, there is agreement in literature on the role of job creation that the informal sector plays (Chen, 2001; Schneider *et al.*, 2010 and Charmes, 2012; Chen *et al.* 2016). The employees of the home-based informal businesses were educated. This is not surprising as Zimbabwe has a literate and educated population. However, informal work seldom requires background training or skills as one usually learns on the job. This was characteristic of most business owners who had no training in the informal work they ran. Gindling and Newhouse (2014) point out that own-account workers' education lies between educated and least educated. The findings of the study reveal that employees of informal businesses were an equal mix of trained and untrained. Families are known to help in home-based informal work, and this was evident in the study. This is characteristic of the informal sector as identified by Chen *et al.* (2016) and Chirisa (2009), when they illustrated segments of the informal sector.

By their very nature, informal businesses usually do not come with benefits, as was the case in the survey. The exceptions were an employer who was the sole proprietor and contributed to a pension, and another who received a transport allowance from the employer. This finding confirms an association between the informal sector and lack of benefits and social protection. It also corroborates the discovery by Horn (2009) and Chen and Sinha (2016) who point out the lack of security in the informal sector. Eapen (2001) also highlights this characteristic and mentions the absence of benefits in the informal sector. Njaya (2015) expands by indicating the absence of security and protection in informal businesses in Zimbabwe. Lack of benefits and social security disadvantages informal businesses as they remain exposed without the full support of the law.

One of the issues that emerged from the study was the lack funding for women to run businesses. Access to finance remains a challenge for women. Ombati and Ombati (2012) and Chigudu (2018) argue that women's minimal skills and limited education limits their access to finance, negatively impacting their barging power with finance houses. By their nature of being small, these home-based businesses do not usually get funded by banks. Moghadam (2007), elaborates by stating that women have an inferior legal status. Hence, women's access to credit is limited and they can seldom produce collateral or credit records required by lending institutions, exposing their diminished bargaining power. However, women are very industrious, and it is no surprise that most women used their own capital to start their business. A considerable number of women also borrowed from family and friends to start their businesses. It also reflects on the strength of their social networks that support them in times of need. These findings agree with the findings of Lighelm (2007) in South Africa. The author's study of informal home-based retail shops pointed out how most shop owners had funded their businesses with money borrowed from family and friends. By their nature of being informal, the study observed that there were no rules of entry into the business and many businesses did not have licenses to operate. Licensing would have been hard to enforce as most of the businesses operated from households. The few offsite businesses existed because their businesses were services provided offsite like hairdressers and event planners. Other women had stalls in the city or locally and operated from there. One implication of operating offsite was payment of fees to use stalls, which was unaffordable for many as it impacted on their bottom-line. Chirisa (2009) also indicated the use of stalls to sell goods by women in the informal sector. Njaya (2015) points out that payment of fees and any other forms of payment are unaffordable for most businesses in the informal sector as their turnover is small, limiting market access.

There were various home-based energy dependent trades employed by women in Harare. The majority were in tailoring, catering and hairdressing. These are trades women naturally find themselves gravitating towards. It is therefore easier to start a business in those fields. Poultry, food processing, retailing, studios and, surprisingly, welding or carpentry were also popular. Contrary to expectations, male dominated trades like carpentry and welding were present in the survey. However, it was usually men that did the work, while women were the administrators. In a few cases, the women took over a family business after a spouse passed away. They usually carried on with the previous employees or the sons ran the business. The ILO (2017) also observed women in male dominated informal work like welding and mining with the women performing the informal work themselves in contrast to the findings of the current study. This highlights how fields are gender-specific in informal businesses but the survivalist nature of the informal sector has crossed the gender divide. Other male dominated trades in the study where women oversaw the business but did not physically do the work included electrical repairs and car washing. Njaya (2015) observed similar electricity dependant businesses and trades among others being performed in Harare. However, these were at places allocated for such operations. These findings may help to explain the scope of informal businesses and lead to the assertion that people in the informal sector practised whatever business was feasible to earn an income and sustain their livelihoods.

Most women (65%) sold their produce or provided their service at home, with 16% selling to the local community at places like stalls or church. Some took their products to the streets or to the clients. However, few sold to local shops, with others having embraced technology and sold online. The home is clearly an indispensable asset for the success of home-based informal businesses. Similar sentiments were shared by (Chen *et al.,* 2016; ILO, 2017). One of the issues emerging from this study is that, unfortunately, home-based informal work will remain unrecognised if it is not visible. The fact that most women sold their produce or provided their services from their homes limits their exposure and potential networking opportunities. It also highlights how their businesses have no access to markets, which ultimately has a bearing on the success of their businesses. Magaisa and Matipira (2017) surveyed SMEs in Zimbabwe's second capital and observed that access to markets hindered the success of SMEs. This observation was supported by Chen and Sinha (2016), who expressed how easy access to markets determined gains made in businesses. Nonetheless, the enterprising women managed to establish commercial networks with clients and companies, including those in the formal sector. This included woman that provided catering services like cakes and food for events like weddings at established venues or regular company events. Others provided chickens or peanut butter to local stores or tailored uniforms for security companies or schools. Hairdressers also had regular clients. This is evidence of linkages between the informal sector and the formal sector. Njaya (2015) associated such interactions as pathways of bridging the gap between the informal and formal sectors.

Sourcing raw materials remains a challenge for the successful running of informal businesses. Wholesalers were the most common source of raw materials as they were easily accessible. However, profit margins were low as they tended to be pricey. Many respondents highlighted how the cost of raw materials was their biggest challenge, negatively impacting on profits. This is also likely due to low capital investment in the businesses. Hence, prices of raw materials and limited access to finance hinder success, with most businesses borrowing from family and friends as pointed out by numerous authors (Lighelm, 2007; Ombati and Ombati, 2012; Chigudu, 2018). Those that managed to source from fresh produce markets had better returns in profits, as these raw materials were cheaper, but transport to access these locations still remained a challenge. Chen and Sinha (2016) highlighted how transport was also a factor that hindered the smooth running of informal business as it was either costly or time consuming, taking away from productive time. The relationship between transport and the ease of doing business was also mentioned by Chirisa (2013) but, in contrast to the current survey, women in informal businesses seldom faced challenges transporting their raw materials or products. Due to the nature of their businesses, they usually found transport at the markets they sourced the goods from. Businesses that imported raw materials had a better chance at pricing their products profitably because they guaranteed good quality. However, sourcing foreign currency to buy the raw materials came with its own challenges. This combination of findings on access to raw material highlights how access and nature of business affect the profit realised.

While sourcing raw materials was a challenge for businesses, selling the produce also had its hurdles, as customers that purchased products or acquired services on credit seldom paid. Hence, debts or non-payment for products or services held back the success of these businesses. This exposed the lack of legal protection for informal businesses as they could not appeal to the courts for non-payment of goods or service provided. Njaya (2015) speaks of the lack of legal and regulatory framework in informal work in Zimbabwe, presenting obstacles for governance in the informal sector. Furthermore, the informal sector has limited access to justice with limited rights apart from those provided for by the constitution. Hence, those in the informal sector face challenges with non-paying customers and recovery of lost income is difficult.

In the study, customers always negotiated the price down, again hindering informal businesses from making substantial profits. The survey points out how product choice determines success in sales, hence one had to understand market trends. This skill was also evident in informal traders that chose goods required daily like bread, over shoes, in the outskirts of Harare as this guaranteed sales and money to take home daily (Chirisa, 2013). Product choice also played a role in the success of the informal businesses under study as markets were flooded with similar products and services, making competition stiff. If a service or product were successful for one, many people would venture into it, flooding the market, for example poultry, tailoring and catering. It took hard work and an impeccable record to grow a client base in those circles and get ahead of the pack. An unfortunate group was those that lost their products during raids by the police, a situation also highlighted by women in the survey by Chirisa (2013). This affected them grossly as recapitalising their businesses was onerous. They usually sold their products in undesignated areas or operated without permits and hence, were always on the lookout for raids. Payment of licenses for hawking or any fees is unaffordable for many businesses in the informal space (Njaya, 2015).

a) Income from informal businesses

Besides the ease of running from home, home-based informal businesses are run from residential homes to reduce overhead expenses that come with operating in business centres. Operating from home eliminates transport and rental costs, while saving time away from home (Horn, 2009; Chen and Sinha, 2016). Home-based informal businesses are indeed a livelihood strategy and survivalist economic activity with actual gains in income earned. Businesses in LDRAs and MDRAs made the most money, with less earned by businesses in HDRAs. This highlights how location of business had a bearing on the income generated from the business. However, informal businesses were practiced in all residential areas, regardless of income. The same sentiments were expressed by Kazimbaya-Senkwe (2004) about home-based informal business location. He found informal businesses in all residential areas, from the wealthy residential areas to the poor. These results support the view that households in Zimbabwe needed means to secure or supplement household income, regardless of their perceived economic status.

There was a strong association between income generated from informal business and operation during power cuts. Business that did not operate during power cuts earned less than those that substituted power sources or used manual equipment. However, the majority of those that used manual equipment earned very little compared to those that substituted energy sources, as their efforts did not go a long way towards being productive during power cuts. Manual equipment was usually time consuming; output was low and tedious. Similar views were expressed by dressmakers in Asia (Chen and Sinha 2016), who mentioned the disadvantages of manual equipment. They expressed how garments where not of similar quality using manual machines. They took longer, had disgruntled customers and lost business. Regardless, substituting energy sources went a long way as those businesses earned a considerable amount of money. An implication of this finding is that productive hours count compared to doing nothing or using manual equipment. Similar sentiments were expressed about productive hours being the most important by garment makers in the study by Chen *et al.* (2016). These findings highlight how energy insecurity impacted urban livelihoods. It also brings to light how those with a low adaptive capacity were impacted the most, hence earned less. These are the vulnerable groups that belong to low-income communities.

5.3.2 Impacts, adaption, and resilience of urban livelihoods to energy insecurity

Electricity use in informal business drives the success of many home-based enterprises. Electricity was mainly used for heating, machine operation and refrigeration. This speaks to the various roles electricity plays in informal business. Access and availability of electricity is crucial. However, power cuts hinder the success of these electricity dependant businesses as also noted by garment markers in Asia (Chen and Sinha, 2016). Most households had electricity cuts in their homes every week, with most businesses perceiving to experience this more in the winter months of the year. This is probably due to the strain national grids take when electricity use increases in winter. The same can be said for long holiday seasons. Most respondents remembered 2013 to 2017 as the years with frequent power cuts, with 2016 being the worst. These years tie in with low lake levels at Kariba Dam in 2015/2016, which resulted in low generation capacity and subsequent power cuts as stated by the ZRA (2016) and NASA (2016). The findings provide further support for the role a climate change-water-energy nexus plays in energy security for Zimbabwe and how that impacts livelihoods. However, it is was somewhat surprising that no respondent married the two.

As power cuts frequently disturbed informal business operations, businesses were energy insecure and had to adapt by finding means to continue working and earn an income when power was cut. However, different households in the various residential areas adapted differently. Most households in the survey substituted energy sources, while the rest did nothing or used manual equipment. The same approach was used by garment makers in informal businesses in Asian cities (Chen and Sinha, 2016). However, garment makers found the use of manual equipment to negatively affect the quality of finished products and to be more tedious and tiring, so breaks had to be taken regularly and productive hours were lost. Residents in HDRAs did not substitute as extensively as other residential areas. This could be associated with limited resources, which left them with no option but to wait for electricity to return. This finding ties in with assumptions made about the economic status of the different residential areas. As observed earlier in the chapter, doing nothing or using manual equipment impacted on the income from informal businesses and was the likely fate of businesses in HDRAs. Their capacity to adapt was limited, making their businesses less resilient to power cuts. What emerges from these findings is that different residential areas have different adaptive capacities to energy insecurity which can be cautiously tied to their economic statuses.

The businesses that substituted for energy mainly used generators. These were more popular in LDRAs and MDRAs than in HDRAs. Firewood was popular in HDRAs, probably because it was a cheaper substitute. This continues to draw attention to the resources and capabilities of residents in HDRAs. Their asset base is low; hence, they have little room to adjust to disturbances to their sources of livelihood. They look for alternatives that are affordable but limit their advancement in the businesses they operate. Businesses found energy substitutes to be expensive, resulting in increased operational cost. They observed that power outages reduced production due to hours lost, resulting in loss of income. Given that power outages impacted their bottom end, businesses adapted differently to protect their income sources. Most opted to increase prices of product or service to recover losses due to power cuts. Those that were able to do so, worked overtime when power was back or diversified income generating projects. The same pattern was also common in Asian cities as home-based informal workers' productivity was affected by power cuts, forcing them to work overtime when power was back (Chen and Sinha, 2016). These findings collectively highlight how low-income groups struggle to adjust during disturbances. Most resort to cheaper alternatives with less gains compared to higher income groups. Higher losses are incurred by groups with the least resources to adapt; hence, energy insecurity due to climate variability impacts the groups with the lowest adaptive capacity.

Productivity was not the only way businesses where impacted. The findings of the survey indicate that besides failing to meet set targets, most businesses had many disgruntled customers as they failed to provide the products or services required. Loss of customers in a flooded market worsened the situation given that building relationships with clients takes time. Similar experiences of loss of customers were experienced by garment makers under Chen and Sinha (2016)'s study. Many products got damaged or spoilt, especially those requiring refrigeration during power cuts. This highlights how energy insecurity disrupts urban livelihoods. The respondents blamed the national economic challenges that the country has been facing on the power outages. They also put blame on the power utility, ZESA, together with lack of maintenance, that results in recurrent faults being experienced. The survey highlighted the population's understanding of electricity challenges in Zimbabwe and the debt it owes the

South African power utility, Eskom. Many were aware that Eskom exported electricity to Zimbabwe and the country did not have enough electricity to meet demand. However, no respondent linked power outages to climate change, weather extremities or drying of Lake Kariba. The Kariba Hydropower Station is well-known by the citizens of Zimbabwe. The citizen's inability to link power cuts to climatic factors could suggest that there is no public awareness of climate change's impacts on water resources and energy security.

Authorities like the city council and national police proved to be a challenge for many businesses. They raided their products, attended to noise complaints from machines and issued fines for businesses that did not have permits. Other studies have highlighted similar experiences by women in informal trading, where police raids were a cause of concern (Chirisa, 2013; ILO, 2017). Some traders opted to pay for licenses to avoid disturbances. The survey was able to rule out the idea that some people ventured into the informal sector to avoid paying rates, taxes or infringing on state legislation. This is in contrast with claims by Edusa and Tribe (1992), where individuals entered the informal economy to avoid state regulations and taxes. The businesses in the current study are unknown to government purely because they have no record of them. The survey also noted that most businesses would thrive in an environment where financial assistance is given by government. Women struggle to get assistance from lending institutions because of unfavourable lending conditions. Many cannot offer lending institutions' preferred collateral, which is usually in the form of property. Cobbe (2002) observed this as a challenge for women as they do not have access to credit, with loans carrying high interest rates and absence of collateral disadvantaging women. Similar arguments were made by Njaya (2015) and the ILO (2017).

An illustration of the key findings of the study and their implications is represented by Figure 5.1 below. It highlights the trends and interactions of hydroclimatic variables and hydropower generation in A and B. It also highlights the existence of a climate change-water-energy nexus in the Kariba sub-basin in

C and how that impacts energy security in an urban system in D to E. The structure of informal businesses and how energy insecurity affects informal trades is illustrated. The adaptation to energy insecurity employed by women in home-based informal work is addressed and ends by highlighting how the most vulnerable groups to the impacts of a climate change-water-energy nexus are the low-income groups. Figure 5.1 brings together how the climate change-water-energy nexus impacts

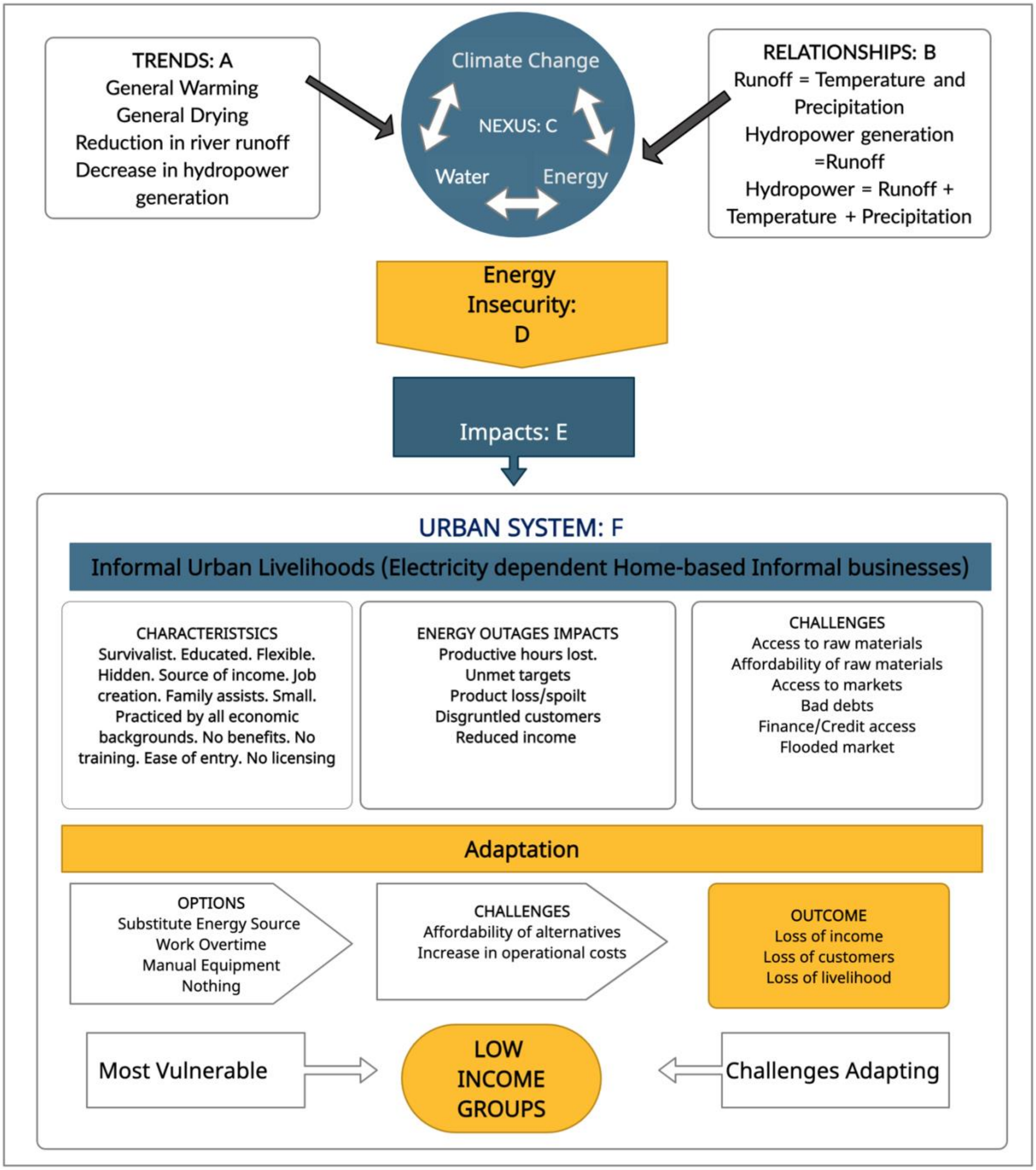

Figure 5.1 The climate change-water-energy nexus and its impacts on urban livelihoods45
Source: Memory Reid

urban livelihoods, exposing the urban poor to be the most vulnerable group impacted the most by this nexus in. this draws attention to the plight of the urban poor, how they lack the adaptive capacity necessary for their sources of livelihood to build resilience to the impacts of climate change.

5.4 The Role of Institutions in Climate Change and its Impacts on Urban Livelihoods.

5.4.1 Climate change and water resources

To address the impacts that a climate change-water-energy nexus has on urban livelihoods, the role of institutions must be included. The findings of the study suggest that government has an overarching role and leads in addressing climate change and its impacts on urban livelihoods. Similar thoughts were shared by Hardy *et al.* (2000) and Dodman and Satterthwaite (2008), where government provides the legislative, financial and institutional direction for various sectors. Other institutions then play individual roles and are sector specific. The institutional role in climate change and water resource management is centred around monitoring and information sharing. These institutions limited their role to data capturing and hardly kept updated scientific publications of the data they collected. This was only done for big projects, usually sponsored by other stakeholders like the World Bank. Here, their role was information sharing. While data collection is important, the information collected is only useful when implemented to improve management of resources. Conway *et al.* (2015) are of the same opinion and argue that data collected in the water sector is seldom used in the operational use of water resources in Southern Africa.

Information is, however, not always readily available. Data sharing happens with ease among institutions but is not accessible in the public domain. Websites have basic information with an absence of processed or analysed data and updated publications or press releases, especially on government websites. In as much as these institutions may not publish regularly, they are not oblivious to the hydroclimatic trends in the country. They all perceived climate change to be happening and observed it in changes in temperature and precipitation. They acknowledge how water resources are threatened by temperature, precipitation, evaporation and wind, as they affect inflows into rivers. They all observed increases in frequency of extreme weather events like droughts and floods. According to ZINWA, the Runde, Mzingwane and Gwayi catchments were observed to have been recording decreases in inflows. Similarities can be drawn to the time series trend analysis of runoff at the Gwayi and Shangani Rivers which are also located in the Gwayi catchment. In addition, they also mentioned that the Zambezi River is volatile with peaks and dips, making it difficult to observe a trend. This was also captured in the study findings.

Collectively, institutions in climate change and water resources management are aware of the climate variability experienced in the country, particularly in the region where the Kariba sub-basin is located. However, their involvement in energy expansion projects is not clear as future expansions are water dependent are in climate sensitive areas of Zimbabwe. Cole *et al.* (2014) has also questioned how much of the scientific knowledge and information is incorporated into the decision-making process of planned dams. In addition, Skinner (2014) questions the success of large projects that involve building dams to store water for energy or other uses. In as much as some dams are transformative in other sectors, they do not involve enough consultations with all stakeholders.

There have been efforts to draw up national response strategies to climate change and water resource management. The findings suggest that government has taken a legislative and leading role in climate change and water resource issues. Climate change has taken centre stage with the drafting of the NCCRS for Zimbabwe. Similar findings by Dodman and Mitlin (2015) highlight government's role in the NCCRS through a National Climate Change Task Team under the president and cabinet. Climate change has also influenced the sustainable use of water, with government drawing up legislature which includes the Water Act and the NCP that serve as guidelines in implementing these strategies. The findings of the study agree with Hardoy *et al.* (2001) and Dodman and Satterthewait (2000) who acknowledged that national government gives legislative, financial and institutional direction around climate change issues.

Government campaigns to desilt dams and repurpose them using techniques like smart agriculture are examples of sustainable use of water resources but require funding and coordinated efforts from stakeholders and local communities. Rasul and Sharma (2016) call for similar multisectoral approaches for successful management of resources. However, the study found that government experiences challenges in securing funding to fully realise its role in such projects, as indicated by ZINWA, due to the dire economic climate. In addition, regulation and compliance become important in the sustainable management of resources but are hindered by limited financial resources to implement and enforce it. Also, water resources are used by many sectors; as such, regulation and addressing of competing needs becomes very important.

Rasul and Sharma (2016) and Urwin and Jordan (2008) highlight how cross-sectoral approaches result in net resilience of all sectors than silo approaches. A UIM system is used to allocate water in Zimbabwe and determines which sector gets priority. Although Zimbabwe is an agriculturally based economy, it relies on rain fed agriculture to cater for its water needs; hence, it is not represented in the UIM system. In a changing climate, there might be a need to rethink this approach as the country is predicted to experience increases in water stress, especially in the semi-arid regions. Conway *et al.* (2015) argue for institutional integration, especially between water and agriculture, to manage the demands for water, especially for energy, improving water security for both sectors.

Zimbabwe has water sitting in its dams which is lost through evaporation as it lacks the infrastructure to deliver the resource to the communities that require it. Illogically, Zimbabwe and South Africa have the highest number of dams in the region (Conway *et al.,* 2015). However, ZINWA indicated that communities are located close to dams but cannot access water from these dams for irrigation or domestic use. Skinner (2014) debates the purpose of damming globally and questions whether it has brought the desired outcomes for many nations. This is well reflected in the case of Zimbabwe. The fact that water sits in dams and is lost through evaporation without being used for intended purposes represents opportunities lost to utilise the resource. The WCD (2000) and Mukheibir (2007) point out that huge evaporative losses occur from large reservoirs and are predicted to increase due to climate change impacts on temperature; hence, these losses will worsen. Zimbabwe's dam situation highlights the drawbacks in improving access to water as largely financial. While government fulfils it legislative role, the financial capacity required to implement and enforce its mandate is a major drawback.

While a coordinated effort in water resource management is evident in Southern Africa through regional bodies like SADC, SACOF, ZAMCOM, ZRA and others, the region has historically faced challenges when natural disasters occur. When droughts and floods hit the region, the blueprint is not realised practically, resulting in devastating outcomes for the region. Droughts, floods, power cuts, overfishing and pollution are such examples. When floods hit the region in recent times (Cyclone Chedza and Cyclone Idai), they left a trail of destruction, destroying infrastructure and disconnecting families (ZAMCOM, 2015; WMO, 2020). The region failed to coordinate management of these extreme events. Muchuru *et al.* (2015) highlight how coordination between sectors, especially across governments, particularly in extreme weather events, needs improvement. He gives an example where the opening of flood gates at Kariba upstream relieved pressure at Kariba but resulted in flooding downstream at Cahora Bassa. This reflects on the need to strengthen regional body structures and coordination in disaster management. According to the IPCC (2007a), frequency and intensity of similar extreme events due to climate change are set to increase, making it mandatory for improvements and preparedness in the region.

5.4.2 Energy Security

The findings of the study through in-depth interviews reveal that energy is a national security issue, and government takes a leading role through the Ministry of Energy and Power Development. It facilitates infrastructure development and the provision of affordable and reliable electricity. ZESA manages the transmission and distribution of electricity through its companies. The ZRA manages the Kariba Dam complex on the Zambezi River, which houses the Kariba Power Station (Tumbare, 2008). The findings highlight the amount of coordination required to successfully deliver and secure energy for Zimbabwe. It also shows government taking the lead and allocating specific functions to other institutions, thus taking a directional role. In the interviews, ZESA indicated that government regulates the price of electricity through subsidies, which are common in Africa, making electricity affordable to many. ZESA has the monopoly on transmission and distribution, with generation open to the public through its companies, ZETDC and ZPC. ZENT and PowerTel Communications focus on investment of ZESA holdings and internet services respectively (Pindula, 2019). However, ZESA highlighted that whoever generates electricity must feed into the national grid at a price regulated by government through the Zimbabwe Energy Regulatory Authority (ZERA). The findings bring to light the challenges faced by IPPs entering the energy space in Zimbabwe. Being small, their profit margin is little or not realized, hence, their role will not grow until competitive pricing is present in the energy sector. An independent energy regulator is unlikely to be appointed as energy is a national security matter and government will want to have some control. However, opportunities should be created to make the market favourable for IPPs. It would improve supply into the grid, augmenting government efforts to provide energy security.

At the time of the interview with ZESA, they indicated that the country had just increased the capacity of Kariba to 1 050MW and was comfortably importing the deficient from the SAPP as foreign currency was not a challenge and the country was fairly stable. The SAPP was the first in Africa to create an integrated network for power sharing for most SADC countries (SAPP, n.d.). According to the interviews with the Ministry of Energy and Power development and ZESA, the country produced less than installed capacity due to obsolete equipment, low lake levels and fuel shortages. Kariba Hydropower contributes more than 50% of electricity for Zimbabwe. This is because the generation of the coal thermal power stations can fall well below installed capacity, as argued by Afshar (2018). The author elaborates by stating, for example, that Hwange Power Station has an installed capacity of 920MW but generates, at best, between 400-500MW, with the rest of the thermal coal power stations rarely generating at all. A similar view is shared by Kaseke (2013) and Brown *et al.* (2012), who highlight that the other thermal power stations in Zimbabwe are old and hardly contribute to the national grid. A few IPPs supply hydropower to the grid, with the largest carrying a capacity of 25MW. Their contribution is minimal when compared to Kariba. Hwange Thermal Power Station is the base load station in Zimbabwe (ZPC, n.d.) but Kariba Hydropower Station is currently the main contributor to the main grid, and as highlighted by ZESA in the interview, is being used as a base load. Collectively, these findings indicate the country's dependence on hydropower and the inefficiency of other technologies in Zimbabwe. It also brings to light the threat to Zimbabwe's energy security of a climate change-water-energy nexus.

Zimbabwe improved capacity of hydropower from the expansions carried out at Kariba Power Station until the dam water level declined again in 2019, causing massive power cuts as the main source of electricity was impacted by climate related events (ZRA, 2019; NASA, 2019). Inflows into Kariba Dam, together with regional weather forecasts from SARCOF, influences ZRA's decisions on water allocation for power generation. One of the issues that emerged is that no institution body can control for weather extremities that often affect the water available in the dam for generation. For nations like Zambia and Zimbabwe, which heavily rely on hydropower, energy security is threatened by climate variability and change. In as much as expansion can be made to improve generation, when there is no water, energy security is compromised. The expansion of Kariba and the drought that came the following year bring up several debates and questions on energy security and climate change. In addition, Zimbabwe is looking into further expanding its hydropower dependence through the Batoka hydro project, which is, surprisingly, located in the same region. Cole *et al.* (2014) is of the opinion that the siting of dams if often dominated by political and fiscal considerations. It appears that the contribution of historic and predicted climate change trends does not strongly influence expansions in dam building for hydropower. Furthermore, in a semi-arid region like the Kariba sub-basin, are expansions in climate sensitive technologies really a means of providing energy security for a country? Though a lot of consultations on its potential environmental impacts have been made, Spalding-Fecher *et al.* (2017) argue that Batoka will not meet the projected capacity. However, that has not stopped plans to continue with the project.

ZESA highlighted in the interview that when generation was low at Kariba in 2015/2016 due to low lake levels resulting from climatic challenges, output was about 250MW at a plant that could give 750MW at that time. However, Imports were limited as the region had no capacity at the time. This undermines the role of the SAPP, where the interconnectedness of power grids allows sharing of electricity when member states experience deficits (SAPP, 2015). The fact that South Africa and Botswana were working on Madupe and Morupule respectively at the time added to the loss of capacity in the region. Some of the issues emerging from this finding relate to two issues. First, it highlights how hydropower reliability is challenged by climate. It also sheds light on the pitfalls in regional energy expansion coordination for the success of the SAPP and security for the region. Additionally, it draws attention to lack of inter sectoral coordination in the region. Furthermore, Spalding-Fecher *et al.* (2017) mention the lack of a body or institution in the region that connects SAPP and ZAMCOM to integrate water resource management and energy. The country had recovered in 2018 during the interview, with dam levels and Zambezi River runoff at peak levels, foreign currency available and energy security almost certain and guaranteed. This situation was obliterated again in 2019 when low dam levels and another dry spell occurred at Kariba, resulting in massive power shortages in Zimbabwe (NASA, 2019; ZRA, 2019).

Despite the historic challenges of hydropower, it is somewhat surprising that the energy sector in Zimbabwe still looks at years of extreme weather events like droughts as cyclic events. These were the general views from the ZRA and ZESA during the interviews. In the interview with ZESA, they mentioned that energy development projects look at least cost, hence generation from hydropower is cheaper than other technologies like thermal. In the same vein, IRENA (2020) points out that generation from hydropower was pegged at 0.037-0.047USD/kWh in 2019 compared to fossil fuel at 0.177-0.050USD/kWh, therefore hydropower expansion is favoured. Batoka Hydro Project, upstream of the Kariba Dam, is one such option, regardless of a negative outlook by studies on the proposed project (Harrison and Whittington, 2002). There is a consensus that using water several times before it continues downstream is a great way to utilise the resource. Although research has highlighted negative gains in a drying climate, it is seen as a solution to secure energy for Zimbabwe, with the benefits seen to outweigh the costs. This project, together with expansion at Hwange and investment in solar energy, are said to increase energy generation and improve the country's energy outlook (ZPC, n.d.). Several of the expansions projected are funded by Chinese banks, whose visibility in Zimbabwe continues to grow. It is also interesting to note that clean energy is seen to be capital intensive and requires a lot of investment which the country cannot afford (REN21, 2020). ZESA mentioned that Zimbabwe also sits on 15 000 years supply of coal; hence, the debate is whether to make use of it over clean technology.

5.4.3 Informal Livelihoods

The SME department fell under the Ministry of Industry and Commerce during the time of interview. The most interesting finding was that government had no direct role in assisting Small and Medium Enterprises (SMEs). It created an enabling environment to indirectly assist SMEs. Similar sentiments were shared by Chigwenya and Mudzengerere (2013) who stated that government encouraged donors and the corporate community to financially support the informal sector in an environment that allows for their involvement in such matters. This indirect involvement of government left the notion that concerns of SMEs are left to the mercy of those they directly deal with like microfinancing houses. Such institutions are capitalist in nature and may therefore not effectively help people in informal work, whose credit rating is low. Njaya (2015) reiterates the same point and goes on to mention that the growth of SMEs is limited by the high rates of credit and finance houses. The position of government of being an indirect player could be why informal businesses are reluctant to be registered as there are no incentives to do so.

Another important and unanticipated finding was that government had no criteria in terms of whom they help. In their eyes, everyone who is willing to do the work gets assistance. They have no programmes tailormade for women as their assistance is not gender specific for fear of being labelled sexist. Although gender neutrality can be considered fair, it certainly does little to lift the efforts of women who clearly dominate the informal sector. Hardoy *et al* (2001) disagrees with this approach as he points out that criteria should be used when assisting vulnerable groups. The marginalised and most vulnerable need to be catered for and women fall into that group. In addition to this, Chigudu (2018) expresses how lack of supportive programmes and insufficient access to credit hampers women's success in SMEs. He argues that it is unproductive not to make use of an educated workforce in the country, hence, creating opportunities directed towards women's businesses is necessary. A significant number of women enter the informal sector, not solely driven by their entrepreneurial interest, but rather out of necessity. The informal trades they perform are survivalist in nature (Chen and Sinah, 2016; Staurt *et al.,* 2018). However, they are resourceful and hardworking, and the income they create goes directly into managing household finances (Eapen, 2001).

Informal businesses are difficult to identify because of their very nature of being informal. Government has been working on a register to get informal businesses out of informal spaces. However, registration is not affordable for most informal businesses (Njaya, 2015). Government regards registration as a pathway to formalising informal businesses, getting them known and recognised, and allocating workspaces for them. The study noted that government efforts in the past have been successful in some areas and not so much in some. One of the issues that emerged was affordability of the trading spaces created, as these usually require a monthly fee. An interesting point was that these spaces are sometimes located in areas that informal businesses regard as having limited traffic for them to sell their products. In the end, these traders end up moving and selling products next to potential customers, abandoning the allocated spaces set up by the city council. A similar trend was observed by Chen and Sinha (2016). They mention how informal businesses place themselves in places that avoid additional expenses like trading fees. It is, however, important to note that home-based informal businesses usually trade at home and do not make use of these spaces. This eliminates rental costs and provides the convenience of working from home while attending to other issues. However, an opportunity is missed to network and increase reach.

Successful informal trading spaces where markets exist and customers come, like the Glen View furniture complex and Gazaland in Highfield, have worked in favour of SMEs. Njaya (2015) observed these types of enterprises, which he described as micro-enterprises, as they fell into that criteria according to the Small and Medium Enterprise Corporation Amendment (2011). These have seen urban livelihoods thrive. It is not surprising that the department of SMEs has plans to increase similar formal workspaces. Again, theirs will be a mediatory role where they bring investors like banks to fund the building of such spaces, negotiate with council to get cheaper land and negotiate with financiers to lower borrowing rates for SMEs. While all this looks good and feasible on paper, the process again leaves informal businesses in the hands of financiers, whose terms are still not attainable for the very small informal business which cannot guarantee paying back loans and hence do not qualify for these loans. The household survey highlighted how the asset base and credit rating of households in HDRAs was low compared to their counterparts in MDRAs and LDRAs. They struggle to capitalise their businesses and to adapt when power outages occur as affordability of options is a challenge for them. Being excluded by a system where government plays an enabling but indirect role disadvantages them and their chances of growing. The resilience of their businesses to disturbances like power cuts is low, hence they need more assistance to grow. Moreover, the ILO (2017) argues that government focuses on assisting registered enterprises. This eliminates most informal businesses that cannot afford to register, as indicated by Njaya (2015). In addition, it leaves informal businesses unrecognised, with insignificant assistance to grow.

Government also sees its enabling role in enacting laws like the SME Act. These regulate micro-financing, where borrowing is at a competitive rate. Hardoy *et al.* (2001) and Dodman and Satterthwaite (2008) reiterate the same and state how governments generally have a legislative role. In the same vein, Chigwenya and Mudzengerere (2013) mention the Small-Medium Policy Framework of 2002 as a legislative step taken by government to assist small businesses. Financial assistance from lending institutions usually comes with payment plans. Again, the home-based informal business does not always meet the criteria of such lending institutions. Hence, such businesses will remain small, with limited capacity to grow. Government needs to do more to assist informal businesses. Magaisa and Matipira (2017) also argue that government can do more to financially support these businesses as part of The National Policy and Strategy for Development for SMEs. They point out that government can improve access to funds for businesses if it acts as a guarantor for SMEs to lending financial institutions. This places government as a direct player in assisting businesses to access finances, especially small and micro businesses that cannot provide collateral for funding. Regrettably, government made it clear in the study that it is not well resourced like first world countries and hence looks to the corporate world and donors to assist in such issues. They also stated that they create networking opportunities like the Zimbabwe Trade Fair, but again, only a few can establish themselves enough to make an appearance there; hence, the informal remain informal, unrecognised and unaccounted for. The situation is even worst for home-based informal business as they are a hidden and unknown group.

A summary of the key findings of the role institutions play in climate change, water resource management, energy security and informal livelihoods is presented below in Figure 5.2. It presents government holding the financial and legislative role, while providing institutional direction and creating an enabling environment which is then implemented by the sectors in climate change, water resource management, energy and the informal sector. It also highlights challenges and opportunities for improvement in the role institutions play in this space. It illustrates finances as one of the challenges faced by institutions in fulfilling their roles. Improvements in institutional integration and energy diversifications can help to secure water and energy in Zimbabwe, limiting the impacts of climate change on urban livelihoods like the informal sector.

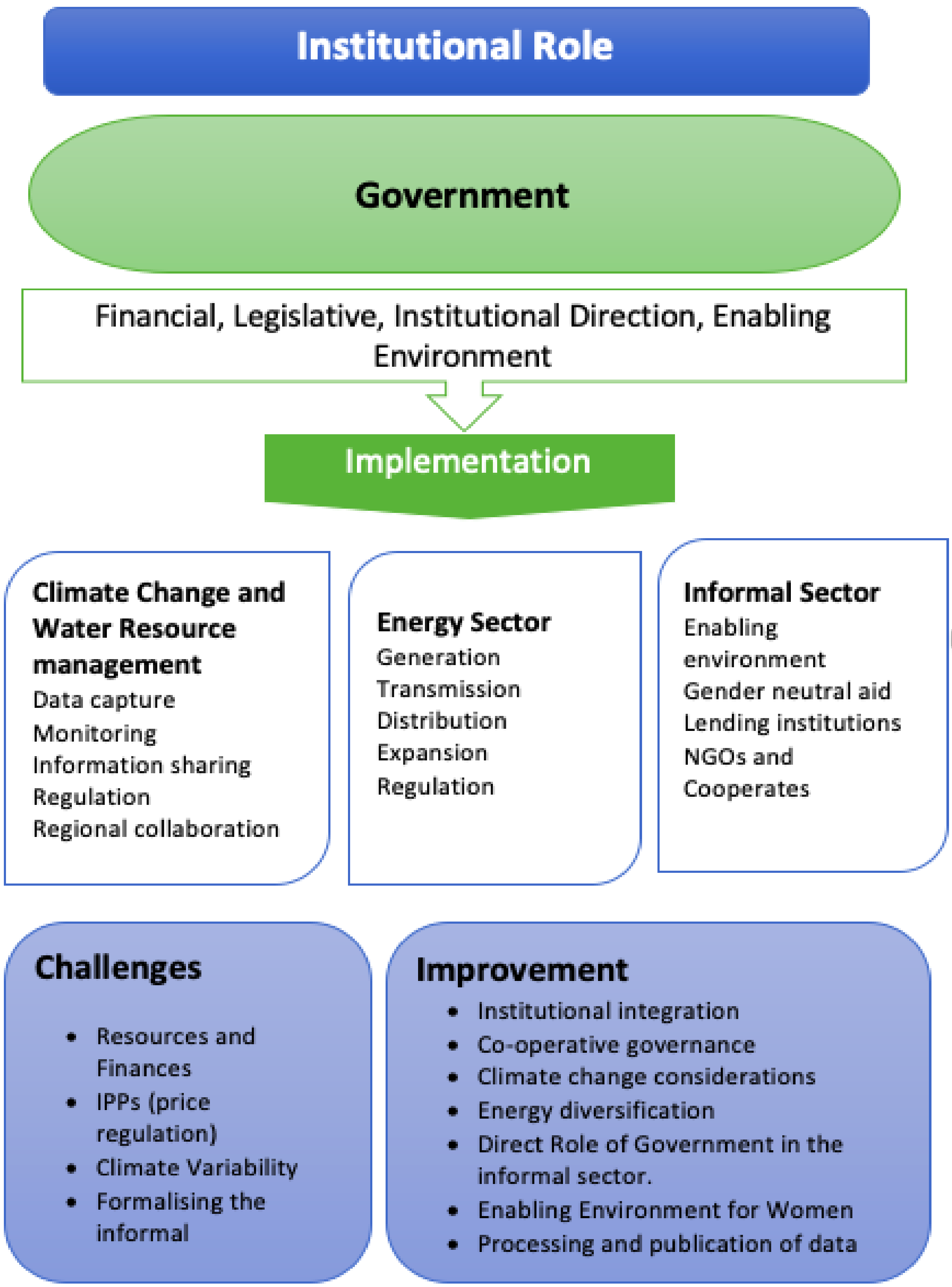

Figure 5.2 institutional role in climate change-water-energy nexus and urban livelihoods46
Source: Memory Reid

5.5 Conclusion

The first two objectives of the study were set on examining the trends and interactions of hydroclimatic variables and hydropower generation in the Kariba sub-basin. The findings helped to show the hydroclimatic trends in the Kariba sub-basin and provided additional evidence on the relationships between hydroclimatic variables and hydropower generation. The combination of these findings adds to a growing body of knowledge on climate change and its impacts on water resources and energy. The trends observed in the Kariba sub-basin indicate an increase in temperature and a decrease in precipitation and runoff. These trends are expected to continue, together with an increase in extreme weather events like droughts and floods (Tadross *et al.,* 2005; New *et al.,* 2006; IPCC, 2007a; Shongwe *et al.*, 2009). With predictions of a warming and drying climate for the semi-arid region of the basin, a reduction in river flow can be expected. Predictions for the basin came to the same conclusion, indicating a decline in river flow by the end of the century (IPCC, 2001; Hamududu and Killingtveit, 2016). This will impact the function of the Kariba reservoir, including electricity generation. Therefore, Kariba Dam's function is compromised through decreased runoff due to climate change, potentially affecting hydropower generation and energy security for Zimbabwe. Hence, a climate change-water-energy nexus exists in the Kariba sub-basin, requiring these sectors to be managed collectively than in silos. Conway *et al.* (2015) calls for an integrated approach in water resource management that involves institutional integration. In addition, Cole *et al.* (2014) calls for transboundary institutional collaboration and co-operative governance to improve resource management and promote energy security for region. These are all necessary for effective management of water resources to secure energy in a changing climate.

The other objectives of the study involved characterising informal businesses in Zimbabwe and analysing how energy insecurity impacted urban livelihoods. Home-based informal businesses displayed typical characteristics of the informal sector. The dependence on energy was visible for successful running of these businesses, with power cuts affecting productivity and reducing income generated. The economic status and asset base of households determined their ability to adapt to energy insecurities. Alternatives were more affordable for households with a higher economic status, hence, their businesses continued to thrive through power cuts. The vulnerability of the urban poor to energy security was evident as they failed to adapt to stresses brought about by power cuts. The group that struggled to adapted and was most vulnerable to electricity outages were the urban poor, highlighting how they are more vulnerable to shocks.

The study objectives also involved looking at the role institutions play in a climate change-water-energy nexus and urban livelihoods. Institutional roles stem from government and funnel down to local level. Government largely takes a leading role with a financial, legislative and institutional direction position. Sectors in the climate change, water resource and energy spaces implement government directives at local level. However, in the informal sector space, government largely plays a legislative role and creates an enabling environment. It has no direct role and leaves that to NGOs and the corporate sector. Increased institutional visibility in all sectors, especially in the informal sector, can assist the growth and recognition of the informal sector, creating opportunities to effectively contribute to the GDP, while creating employment and supporting livelihoods. The present study makes noteworthy contributions to a growing body of literature on the climate change-water-energy nexus and urban livelihoods. The empirical findings of this study provide a new understanding of the impacts of a climate change-water-energy nexus on urban livelihoods.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This final chapter of the thesis concludes the study by putting together the findings of the research and recommendations on the subject area. It comprises three main sections drawn from the study. The first section summarises the key findings of the study and how they align with or diverge from the research questions that framed the research. The summaries of the study findings are highlighted, and their implications explored. The chapter goes on to present recommendations on the issues discussed in an effort to inform decision making processes on those matters. It draws up recommendations for practitioners, policy makers and academia. The third section outlines areas of possible future research informed by identified knowledge gaps.

6.2 Summary of Key Findings

This study was prompted by five research questions that looked at:

1) the inter-annual climatic, hydrological and hydropower generation trends observed in the Kariba sub-basin,
2) the relationships among the climatic, hydrological and hydropower generation trends in the Kariba sub-basin,
3) the make-up of the informal enterprises in the urban areas of Zimbabwe,
4) energy insecurity and how it affects the informal sector as a source of urban livelihood,
5) the roles institutions play in the sectors of climate change, water, energy and urban livelihoods.

Efforts to answer these questions involved examining data from various fields including climate, energy, water resource management and informal business, to name a few. The summaries of what the study established, and the consequences of these findings are presented below.

6.2.1 Hydroclimatic and hydropower trends and relationships in the Kariba sub-basin

The Kariba sub-basin has become warmer over the years as shown by a warming trend for annual and seasonal maximum temperatures. Changes in climate have already been felt and is predicted by other researchers to continue. Minimum temperatures showed a decreasing trend at all stations but were only significant in Victoria Falls during the wet season. This finding was unexpected as there was an increasing trend in maximum temperatures and other authors observed an increase in both minimum and maximum temperatures in the ZRB.

A decreasing trend in annual and seasonal precipitation was observed, implying that the Kariba sub-basin has been getting drier. The decreasing trend is projected to continue, threatening water availability in the region. Annual river runoff of all rivers showed a decreasing trend, apart from the Zambezi River. This finding suggests the Zambezi River is highly variable. Reduction in river runoff has negative implications for water resource use in the Kariba sub-basin. This was evident as hydropower output showed a decreasing trend, implying a reduction of electricity generated over the years. The annual precipitation, river runoff and hydropower output trends in the study sites of the Kariba sub-basin mimic historic extreme weather events like droughts and floods in the ZRB. This highlights how the Kariba sub-basin, like the ZRB, is prone to extreme weather events, and highlights the sensitivity of the basin to extreme climatic events. This sensitivity for the Kariba sub-basin, where the Kariba Hydropower Station is located, has a bearing on hydropower output and energy security in Zimbabwe. The overall findings in the Kariba sub-basin indicate a warming and drying trend, with reduced runoff and hydropower output.

Temperature and precipitation impact on with runoff at Victoria Falls. This relationship calls attention to how climatic factors impact water availability and storage in the Kariba sub-basin and the sensitivity of runoff to climatic factors in the basin. Hydropower dependency on runoff, was also evident, bringing out a water-energy nexus. Furthermore, hydroclimatic (temperature, precipitation and runoff) factors impacted on hydropower generation in the Kariba sub-basin. If the observed warming and drying years continue, hydropower output is reduced, impacting energy security of Zimbabwe. The trends and relationships of hydroclimatic variables and hydropower output suggest a climate change-water-energy nexus exists for the Kariba sub-basin, with implications on energy security of Zimbabwe.

6.2.2 Characteristics of women in home-based informal businesses and energy insecurity in Zimbabwe

Women in home-based informal businesses are educated and headed most the households studied. Most women venture into the informal sectors as a survivalist economic activity; hence, most households' sources of income were mainly from informal enterprises and formal employment. Contrary to expectations, the highest earnings were found in HDRAs though that is where low-income earners are presumed to live. However, residents in LDRAs had a higher asset base as they purchased their houses and had not received allocations like those in HDRAs. They also owned more than two vehicles.

Most businesses were own-account businesses as women in informal businesses are usually self-employed, thus empowering women. Home-based informal businesses created employment and were small, with the average number of people operating in the business being two. While the employees were educated, they did not automatically have training or skills in the jobs they performed. The same applied to employers, as many learnt the skills on the job. Home-based informal work did not come with benefits and seldom gets funding form lending institutions. Most women capitalised their businesses with money borrowed from family and friends. There were no rules of entry into the business. The most common energy dependent trades were tailoring, catering and hairdressing, with male dominated trades like welding and carpentry were also being practiced by women in home-based informal trades.

Home-based informal work remains unrecognised as most women sold their produce or provided their services from their homes. Most informal businesses found raw materials to be costly. Women in the home-based informal sector had no legal rights, hence they struggled to collect bad debts. On top of bad debts, markets were usually flooded by the same products. Some of these products were subjected to raids by police when sold in undesignated areas. Location of business influenced income created in home-based informal work. Furthermore, businesses that were able to adapt and substitute energy sources during power cuts made higher earnings compared to those that used manual equipment or did not operate during power cuts.

Electricity was fundamental for home-based informal work. However, power cuts, which occurred weekly, disrupted these trades. They were worse in winter months and during long holidays when electricity use was at its highest. This power cuts where perceived to be at their worst in 2016, which tied in with low water levels at Kariba Dam in the 2015/2016 season. However, the women in the survey did not connect power cuts to low dam levels at Kariba or climate change. Power cuts forced women in home-based businesses to adapt by mainly substituting energy sources. Generators were most popular although businesses in HDRAs used firewood as it was a cheaper alternative. This highlighted the limited resources and capabilities of HDRAs. This finding suggested that economic status had a bearing on ability adapt to energy insecurity, exposing the vulnerability of the urban poor to energy insecurity. Energy substitutes were expensive for all businesses, increasing their operational cost. Most businesses opted to increase product or service price to recover losses and expenses due to power cuts.

Power cuts affected how home-based businesses' customer relations morphed, as set targets were not met, leaving many disgruntled customers. Product loss was another common problem, especially spoilt products that required refrigeration. Many viewed the constant power cuts to be because of the country's economic challenges, with no respondent linking the power cuts to low dam levels at Kariba Dam. Women got into informal trades as means to earn an income for their households rather than evading regulation, although they were constantly raided by authorities. They expressed that financial assistance would go a long way towards capitalising their businesses.

6.2.3 Institutions and their role in climate change and urban livelihoods

Climate change issues are led by government, while other roles are sector specific. Institutions in climate change and water resource management focus on monitoring and information sharing, but seldom publish data into the public domain. Institutions in the climate and water resource space were not oblivious to climate change and have observed change in hydroclimatic variables and increases in extreme weather events. Climate change national response strategies were drawn up, together with legislation like the NCP to tackle climate related issues, with regulation and enforcement of climate and water resource use still a challenge. The country uses a UIM system to allocate water and to address competing needs. Water resource management is regionally coordinated through SADC. However, improvements could be made on how to deal with extreme weather events as these are set to increase in frequency and intensity in the region.

Government takes a leading role in the energy sector through the Ministry of Energy and Power Development, as energy is a national security matter. While the ministry oversees infrastructure development and energy security, ZESA manages transmission and distribution of electricity. Whilst generation of electricity is open to any player; government regulates pricing of electricity, which is not competitive enough for IPPs to realise a reasonable profit. The ZRA manages the Kariba complex where hydropower is generated from the Kariba Hydropower Station. It is the main source of hydroelectric power and currently the main contributor to the main grid with 1 050MW capacity. Weather extremes like droughts have highlighted hydropower's sensitivity to climate change. This has not stopped Zimbabwe from working on expanding its hydropower capacity, with Batoka Hydropower Project on the cards. The country uses a least cost approach in energy development, and this favours hydropower.

Government has no direct role in assisting SMEs but creates an enabling environment that benefits the SMEs. This includes enacting laws like the SME Act. Such legislature allows SMEs to get funding at competitive rates from lending institutions. However, the terms remain steep for smaller businesses like those practiced by women in home-based informal trades. This limits the financial assistance that can be afforded to women in home-based informal work as their credit rating is low since most do not have the collateral needed for loans. Government has no criteria for assisting small business and no gender specific programs for women in informal businesses. However, the sector is dominated by women hence a more direct effort to assist helps capitalise their businesses and earn decent income. Government is creating a register of informal businesses to formalise them. It is also working on building more workspaces for the informal sector to improve networks and market access.

6.3 Recommendations

This research proposes various recommendations to help establish energy security for Zimbabwe, while protecting the livelihoods of home-based informal businesses in a changing climate. The outcomes of this study indicate historic changes in hydroclimatic and hydropower generation trends, with relationships present for these variables. Hence, climatic variables have a bearing on runoff and hydropower. This suggests a climate change-water-energy nexus exists in the Kariba sub-basin. With the observed trends predicted to continue in the future, they have the potential to continue to impact energy security as they have historically done in Zimbabwe. The study has also highlighted how energy insecurity, through frequent power cuts in Zimbabwe, has impacted urban livelihoods like the informal sector. Therefore, it is important to secure energy security for Zimbabwe and protect urban livelihoods from a climate change-water-energy nexus.

The following are recommendations from the study:

i. Considerations should be made on incorporating an energy mix that does not depend solely on a technology historically affected and predicted to continue to be affected by climate change. Dependency on hydropower is evident in Zimbabwe and future projects like the Batoka are in the same region predicted to be negatively impacted by climate change. Special attention should be given to other technologies that are in abundance and not harnessed fully in the region like wind and solar. Diversifying the energy mix is a strategy that would help secure energy.
ii. In its efforts to diversify the energy mix in Zimbabwe and improve energy security, government has limited its focus to continuous repair and expansion of old stations as new energy sources are costly and take years to develop. However, focus should increase on renewables that can be rapidly developed and utilised, while decentralising electricity by setting up mini grids in places like schools and hospitals, especially those that are yet to get electrified.
iii. There is need to "climate proof" Southern Africa's energy sector. The region needs to reassess future energy development plans while modifying existing infrastructure by implementing techniques that can adapt to the variable climate in the region. The ultimate goal would be to develop energy systems that match the climatic patterns, while developing technologies that are suited to future climatic scenarios in the region.
iv. Southern Africa needs to improve coordination in regional energy expansion plans that leave the region with surplus energy for export. An integrated approach and strategic planning in energy development helps the region get ahead of the impacts of climate change. This assists other nations when they cannot meet their demands, especially due to unforeseen events like drought, while simultaneously strengthening the region's energy security.
v. Government needs to create an enabling environment that increases the footprint of IPPs in Zimbabwe. While government is highly unlikely to use

an independent regulator as energy is a national security matter, efforts can be made to create a competitive market in the energy sector. This would allow other players to contribute to the grid, adding to the installed capacity.

vi. Institutions captured data but seldom processed or published it unless there was a project that compelled them to do so. Development of big data should be explored. It is important to set up big data that is accessible to the public for more research. This would also encourage the establishment of research units that would periodically publish on the climate outlook of the region. Improvement in data capturing, sharing and research helps diminish the impacts of climate change in the region.

vii. A change in perception by urban planners and policy makers is needed for the recognition of home-based informal livelihoods. Rather than penalising home-based informal businesses, purposeful considerations should be made about future urban land use plans to accommodate home-based informal businesses.

viii. There is need to improve labour force surveys to include home-based informal work as a source of livelihood. Most women practiced their trades and sold their produce from their residences. Enumerators need to be trained to identify them. This improves recognition of women in home-based informal work, allowing them to have a voice to improve their position and bargaining power.

ix. Government should be compelled to take a more direct role in assisting the informal sector from funding to gender specific programs. While it creates an enabling environment for informal businesses, it is not enough as the direct benefits of such pathways do not always benefit the groups that most need assistance. They are left at the mercy of other stakeholders like lending institutions which have borrowing criteria that informal businesses cannot meet.

x. The informal sector needs to improve visibility so as to be recognized in the marketplace, increasing chances of financial assistance, market assess and business training. One way would be to increase participation in unionised or organized groups that make them more visible.

6.4 Future Research

Based on the findings of this research, future research endeavours are suggested as highlighted below.

i. Further research into the impacts of climate change on other energy technologies should be explored. While the impacts of climate change on hydropower are more obvious, other technologies consume large amounts of water, which is predicted to grow in scarcity. Such research is scarce in Africa, yet it is one of the regions set to be hardest hit by climate change. This also gives a wholesome insight into energy security for many regions.
ii. Another possible area of research would be to investigate climate change impacts on ground water. Surface water availability in relation to climate change has received more attention in research with less interest in ground water, which contributes immensely to water security.
iii. There is evidence of extensive data capturing in the sectors of climate, water and energy in Zimbabwe. More research to trace operational use of data captured in the sectors of climate change, water and energy would be valuable.
iv. More research on the impacts of climate change on urban livelihoods in cities is necessary as studies in this area are limited. Research on climate change impacts on livelihoods is centred more around rural livelihoods than urban livelihoods due to the agrarian based livelihoods in rural areas. However, climate change impacts on urban livelihoods are equally important as urban populations continue to rise. Hence, it is necessary to secure urban livelihoods. In addition, it would be interesting, for example, to carry out a cross-national study that compares climate change impacts on urban livelihoods in different cities. Urban systems are complex and absorb stresses and shocks differently. The adaptive strategies in different

cities and the role institutions play provide different approaches in adapting to climate change, creating opportunities to develop frameworks and policies around such matters.

v. More research on climate change modelling that integrates the impacts of climate change on various sectors in Africa is required. Hence, research that looks at a multidimensional approach to climate change modelling would be beneficial.

vi. Further research needs to examine the role institutions play in supporting urban livelihoods in a changing climate more closely. This is because urban systems are complex and vulnerable groups are impacted most by shocks, therefore they require greater consideration. Urban spaces are largely commoditised, hence the need to safeguard livelihoods.

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Appendices

Appendix A: Research Participant Consent Form

CONSENT FORM

THIS IS MEANT FOR ALL RESEARCH PARTICIPANTS

I hereby confirm that I have been well informed in the language I fully understand (English/Shona); by study investigator Mrs Memory Reid about the nature, conduct, benefits and risks of the study. I have also received, read and understood the participant information sheet regarding the study. Although anonymity cannot be guaranteed where a referral method of selection was used, I am aware that the information provided will remain confidential and used for academic purposes only, whose results will be available in the school library and/or published in academic journals. I am aware that at any stage without prejudice I can withdraw my consent and participation in the study. I have had sufficient opportunity to ask questions (in English or Shona) and therefore, I declare that; I am/more than at 18 years of age and prepared to voluntarily participate in the study.

(Tick where it is relevant)

- I do agree to participate in the survey. ☐
- I do not agree to participate in the survey. ☐

PARTICIPANT' S

Signature -- Date---------------

I, **Memory Reid**, herewith confirm that the above participant has been fully informed about the nature and conduct of the above study in the language they fully understand (English/Shona).

RESEARCHER

Memory Reid

Signature -- Date--------------

Appendix B: Private Sector Participant Information Sheet

Private Sector Participant Information Sheet

Principle Investigator : Memory Reid

Student Registration Number : 400526

Research Topic: Perspectives on the Impacts of Climate Change and Energy Security on Urban Livelihoods of Poor Households in Harare, Zimbabwe.

A. Preamble

Dear Sir/Madam,

I am Memory Reid, a student at the University of the Witwatersrand, Johannesburg, in the School of Geography, Archaeology and Environmental Studies. I am studying towards a PhD. My research is on the Impacts of Climate Change and Energy Security on Urban Livelihoods of Poor Households in Harare. I am requesting your participation in my study by inviting you to participate in an interview process which would take about thirty minutes maximum duration. If you decide to participate in this research, I would like to request you to sign a consent form to confirm acceptance to be part of this research process.

B. Purpose of the study

This research focuses on climate change and energy security on livelihoods in Zimbabwe, with particular interest in the informal sector. Basically, I am investigating power shortages issues and how they affect people in the informal sector. You were chosen to participate in this research process because you work in an institution whose function is relevant to my research interests. Thus you could help provide information pertaining to this research topic. It is therefore important to mention that the information you will provide will be used for academic purposes only.

C. Procedure

This interview process will be conducted in your place of work unless advised otherwise by yourself. The researcher will take notes during the interview process. The interview will be conducted in English with the option of switching to the local language (Shona) were there is need as the researcher is fluent in Shona as well.

D. Potential risks and benefits to participant

There are no risks involved in taking part in this research process. Participation in this research process is voluntary and no fee will be paid. There are no direct benefits from participating in this study and there are no disadvantages or penalties for not participating. This study will be used for academic purposes only and will contribute to the body of knowledge on the relationship between climate change and energy nexus and the informal sector in Zimbabwe.

E. Confidentiality and Anonymity

Unless advised otherwise by the participant, contributions may potentially be identifiable in a final research report even if pseudonyms are used. During the interview process will you be asked to identify your position in the organization/institution but may choose to not indicate your name or any personal information that can be used to identify you later on. You are also free to stop the interview or skip any question that you find offensive/uncomfortable answering. You may also withdraw at any time without any consequences or any explanation.

The data collected from this research will be used for academic purposes only. They will be compiled into a PhD thesis through publication in scientific journals and submitted to the Faculty of Science, University of the Witwatersrand. Any information that may identify you or any references made in this study will not be disclosed but will give reference to your organization/institution. The results would be accessed through the University website and Wits library archives open to all registered students and staff of the University. If you wish to receive a summary of this report, I will be happy to send it to you upon request.

F. Researcher contact details

For further information regarding the research or the implication of your participation, please do not hesitate to contact me or my supervisor on the details below. If you have any queries, concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (non-medical), telephone + 27(0)11 717 1408, email hrec-medical.researchoffice@wits.ac.za/ Shaun.Schoeman@wits.ac.za

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Appendix C: Public Sector Participant Information Sheet

Public Sector Participant Information Sheet

Principle Investigator : Memory Reid

Student Registration Number : 400526

Research Topic: Perspectives on the Impacts of Climate Change and Energy Security on Urban Livelihoods of Poor Households in Harare, Zimbabwe.

A. Preamble

Dear Sir/Madam,

I am Memory Reid, a student at the University of the Witwatersrand, Johannesburg, in the School of Geography, Archaeology and Environmental Studies. I am studying towards a PhD. My research is on the Impacts of Climate Change and Energy Security on Urban Livelihoods of Poor Households in Harare. I am requesting your participation in my study by inviting you to participate in an interview process which would take about thirty minutes maximum duration. If you decide to participate in this research, I would like to request you to sign a consent form to confirm acceptance to be part of this research process.

B. Purpose of the study

This research focuses on climate change and energy security on livelihoods in Zimbabwe, with particular interest in the informal sector. Basically, I am investigating power shortages issues and how they affect people in the informal sector. You were chosen to participate in this research process because you work in an institution whose function is relevant to my research interests. Thus you could help provide information pertaining to this research topic. It is therefore important to mention that the information you will provide will be used for academic purposes only.

C. Procedure

This interview process will be conducted in your place of work unless advised otherwise by yourself. The researcher will take notes during the interview process. The interview will be conducted in English with the option of switching to the local language (Shona) were there is need as the researcher is fluent in Shona as well.

D. Potential risks and benefits to participant

There are no risks involved in taking part in this research process. Participation in this research process is voluntary and no fee will be paid. There are no direct benefits from participating in this study and there are no disadvantages or penalties for not participating. This study will be used for academic purposes only and will contribute to the body of knowledge on the relationship between climate change and energy nexus and the informal sector in Zimbabwe.

E. Confidentiality and Anonymity

Unless advised otherwise by the participant, contributions may potentially be identifiable in a final research report even if pseudonyms are used. During the interview process will you be asked to identify your position in the organization/institution but may choose to not indicate your name or any personal information that can be used to identify you later on. You are also free to stop the interview or skip any question that you find offensive/uncomfortable answering. You may also withdraw at any time without any consequences or any explanation.

The data collected from this research will be used for academic purposes only. They will be compiled into a PhD thesis through publication in scientific journals and submitted to the Faculty of Science, University of the Witwatersrand. Any information that may identify you or any references made in this study will not be disclosed but will give reference to your organization/institution. The results would be accessed through the University website and Wits library archives open to all registered students and staff of the University. If you wish to receive a summary of this report, I will be happy to send it to you upon request.

F. Researcher contact details

For further information regarding the research or the implication of your participation, please do not hesitate to contact me or my supervisor on the details below. If you have any queries, concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (non-medical), telephone + 27(0)11 717 1408, email hrec-medical.researchoffice@wits.ac.za/ Shaun.Schoeman@wits.ac.za

Researcher's Contact	**Supervisor's Contact**
Memory Reid	Professor Danny Simatele
Phone No: +27 760887621.	Phone No: +27 0117176515
email address: memoryreid@gmail.com	Mulala.simatele@wits.ac.za
400526@students.wits.ac.za	

Appendix D: Household Survey Participant Information Sheet

Household Survey Participant Information Sheet

Principle Investigator : Memory Reid

Student Registration Number : 400526

Research Topic: Perspectives on the Impacts of Climate Change and Energy Security on Urban Livelihoods of Poor Households in Harare, Zimbabwe.

A. Preamble

Dear Sir/Madam,

I am Memory Reid, a student at the University of the Witwatersrand, Johannesburg, in the School of Geography, Archaeology and Environmental Studies. I am studying towards a PhD. My research is on the Impacts of Climate Change and Energy Security on Urban Livelihoods of Poor Households in Harare. I am requesting your participation in my study by inviting you to participate in a research questionnaire which would take about thirty minutes maximum duration. If you decide to participate in this research, I would like to request you to sign a consent form to confirm acceptance to be part of this research process.

B. Purpose of the study

This research focuses on climate change and energy security on livelihoods in Zimbabwe, with particular interest in the informal sector. Basically, I am investigating power shortages and how they affect people in the informal sector. You were chosen to participate in this research process because you are working in the informal sector, participating in home based informal employment that is dependent on electricity. Thus you could help provide information pertaining to this research topic. It is therefore important to mention that the information you will provide will be used for academic purposes only.

C. Procedure

The questionnaire will be administered by the researcher at your place of work unless advised otherwise by yourself; in this case your home is your place of work. You will be asked questions by the researcher in English and asked to answer in English and response taken down in the questionnaire by the researcher. The researcher is also in a position to translate and ask the questions in the local language (Shona); accepting responses in Shona in situations where the respondent cannot read write or understand English or where further clarity is needed by the respondent.

D. Potential risks and benefits to participant

There are no risks involved in taking part in this research process. Participation in this research process is voluntary and no fee will be paid. There are no direct benefits from participating in this study and there are no disadvantages or penalties for not participating. This study will be used for academic purposes only and will contribute to the body of knowledge on the relationship between climate change and energy nexus and the informal sector in Zimbabwe.

E. Confidentiality and Anonymity

Unless advised otherwise by the participant, contributions will be strictly anonymous and results confidential. In cases where recruitment of the participant to the study was through a referral method (snowball method), anonymity cannot be guaranteed but information provided will not be disclosed to anyone including the person/s that referred the researcher to the participant, hence remain confidential. At no point during the interview process will you be asked to indicate your name or any personal information that can be used to identify you later on. You are also free to stop the interview or skip any question that you find offensive/uncomfortable answering. You may also withdraw at any time without any consequences or any explanation.

The data collected from this research will be used for academic purposes only. They will be compiled into a PhD thesis through publication in scientific journals and submitted to the Faculty of Science, University of the Witwatersrand. Any information that may identify you or any references made in this study will not be disclosed. The results would be accessed through the University website and Wits library archives open to all registered students and staff of the University. If you wish to receive a summary of this report, I will be happy to send it to you upon request.

F. Researcher contact details

For further information regarding the research or the implication of your participation, please do not hesitate to contact me or my supervisor on the details below. If you have any queries, concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (non-medical), telephone + 27(0)11 717 1408, email hrec-medical.researchoffice@wits.ac.za/ Shaun.Schoeman@wits.ac.za

Researcher's Contact	**Supervisor's Contact**
Memory Reid	Professor Danny Simatele
Phone No: +27 760887621.	Phone No: +27 0117176515
email address: memoryreid@gmail.com	Mulala.simatele@wits.ac.za
400526@students.wits.ac.za	

Appendix E: Household Survey Questionnaire

University of the Witwatersrand
Faculty of Science
School of Geography, Archaeology and Environmental Studies

Survey Questionnaire for Home-Based Electricity Depended Informal Work

Questionnaire Number ………..

SECTION A

SOCIO-ECONOMIC DEMOGRAPHICS

Reference to head of household.

1. Gender. **Male** ☐ **Female** ☐
2. Age. **Years……………………..**
3. Marital Status. **Married** ☐ **Single** ☐ **Widowed** ☐ **Divorced** ☐
4. Level of education. **Primary School** ☐ **High School** ☐ **Tertiary** ☐ **Other (please specify)** ☐

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…………………………………………………….

5. Occupation/Employment Status. **Full Time** ☐ **Part Time** ☐ **Informal** ☐ **Unemployed** ☐ **Retired/Pensioner** ☐ **Other (please specify)** ☐

……………………………………………………………………………………………………

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Reference to spouse if applicable (tick N/A box if it applies) **N/A** ☐

6. Gender. **Male** ☐ **Female** ☐
7. Age. **Years……………**
8. Level of Education. **Primary School** ☐ **High School** ☐ **Tertiary** ☐ **Other (please specify)** ☐**……………………………………………………………………….**
9. Occupation/Employment Status. **Full Time** ☐ **Part Time** ☐ **Informal** ☐ **Unemployed** ☐ **Retired/Pensioner** ☐ **Other (please specify)** ☐

……………………………………………………………………………………………………
……………………………………………………..

Household structure

10. Gender distribution. **Males……………** **Females…………….**

11. Ages distribution of household members. **<12years……………. 12 -17 yrs……………. 18 - 35 yrs youth…………… 36 - 65 yrs adults…………… 65 > old age……………..**

12. Level of Education of household members**. Primary School☐ High School☐ Tertiary ☐ Other (please specify) ☐**

………………………………………………………………………………………… ………………………………………………….

13. Occupation/Employment Status of household members. **Full Time☐ Part Time ☐ Informal ☐Unemployed ☐ Retired/Pensioner ☐ Other (please specify) ☐**

………………………………………………………………………………………… …………………………………………………..

Household Income and finances

14. Sources of income in household. **Salaries/Wages ☐ Savings☐ Pensions☐ Remittances☐ Informal enterprise ☐ Other (please specify)☐**

………………………………………………………………………………………… …………………………………………………..

15. Total monthly household income**. <$100 ☐ $101 - $300☐ $301 - $500☐ $501 - $1000☐ $1001 - $3000☐ $ 3001 - $5000 ☐ $5001 >☐**

16. Total monthly household income from informal home based work under study.

<$100 ☐ $101 - $300☐ $301 - $500☐ $501 - $1000☐ $1001 - $3000☐ $ 3001 - $5000☐ $5001 > ☐

17. Proportion of household income from informal home based work as a percentage**……….%**
(in the event respondent is not comfortable disclosing income generated)

18. Do you have access to credit? **Yes ☐ No ☐**

19. Which type of credit? **Bank☐ Employer/Work☐ Group Rotations☐ Loan Shark☐ Other (please specify)☐**

………………………………………………………………………………………… …………………………………………………..

20. Have you been paying a loan in the last 2 years? Yes☐ No ☐

Property/Housing

21. Property Ownership. **Purchased/Mortgage ☐ Rental☐ Inherited ☐ Allocation ☐ Other (please specify) ☐**

………………………………………………………………………………………… …………………………………………………..

22. Number of bedrooms. **1 ☐ 2☐ 3 ☐ 4 ☐ 5☐ 5 > ☐**

23. Size of Stand. **<500m²** ☐ **501 - 1000m²** ☐ **1001- 2000m²** ☐ **2001 - 3000m²** ☐ **3001m²** ☐

Other Assets

24. How many cars do you have? **0** ☐ **1** ☐ **2** ☐ **3** ☐ **3 >** ☐

25. How many TVs do you have? **0** ☐ **1** ☐ **2** ☐ **3** ☐ **3 >** ☐

26. Do you subscribe to DSTV (paid tv)? **Yes** ☐ **No** ☐

27. Do you own a four plate stove or refrigerator? **Yes** ☐ **No** ☐

Other Demographics

28. Do you belong to any social groups or committees in the community? **Yes** ☐ **No** ☐

29. Which ones**?** **Church Choir/Member** ☐ **Neighborhood watch** ☐ **Other (please specify)** ☐ **……………………………………………………………………**

SECTION B

HOME-BASED ENTERPRISE

Structure of the enterprise

1. Type of enterprise. **Own-Account Enterprise** ☐ **Enterprise of employers** ☐ **Contributing family workers** ☐ **Cooperative** ☐ **Other (please specify**) ☐ **……**

2. When did you start the business? **Year……………**

3. How long has the business been operating? **Years……………**

4. Are there any rules of entry into the business? **Yes** ☐ **No** ☐

5. If **YES above (4),** please explain **……..**

6. Do you only operate this business from your home only? **Yes** ☐ **No** ☐

7. If **NO above (6),** elaborate ………

………………………………………………………………………………………………
………………………………

8. Do you have a license from the council to run the business? **Yes** ☐ **No** ☐**Other (please specify)**☐
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9. If **YES above (8),** explain the type of permit and if NO explain why not.
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10. How did you get capital or money to start the business? **Did not need any capital** ☐ **Used own capital** ☐ **Used household income capital** ☐ **Borrowed from family/friends** ☐ **Acquired a loan** ☐ **Other (please specify)** ☐
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Goods/Services of the enterprise

11. What does your enterprise engage in or produce?
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12. Who is your target market?
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… 13. Where units produced sold?
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… 14. Where are the raw materials sourced from?
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… 15. What challenges do you face sourcing raw materials?
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…116. What challenges do you face selling your produce/ providing your service?
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Employment structure and conditions of the enterprise

17. How many people are employed in the enterprise? **Own-Account** ☐ **Full-time** ☐ **Part-time** ☐

18. Do family members assist you in the business? **Yes** ☐ **No** ☐

19. What is the level of education of the employees**?** **Primary School** ☐ **High School** ☐ **Tertiary** ☐ **Other (please specify)** ☐
……..

20. Did you receive any skills training for the work that you do? **Yes** ☐ **No** ☐

21. Did the employees receive any skills training for the work that they do? **Yes** ☐ **No** ☐

22. Do the employees receive any benefits? **Medical insurance** ☐ **Pension** ☐ **Paid leave** ☐ **Other (please specify)** ☐
……….

Energy and business operation

23. What does the enterprise use electricity for?
……..

24. Do you experience power outages or load shedding in your enterprise operation?
Yes ☐ **No** ☐

25. If **YES**, above **(24),** how often do you experience the load shedding? **Daily** ☐ **Weekly** ☐ **Monthly** ☐ **Other (please specify)** ☐
……….

26. What is the average duration of these power outages on a given day? **Hours**……………

27. What time of the year are power outages at their worst?
……….

28. What period or years do you recall when power outages were at their worst?
………

29. How do you continue to work when there are power outages? **Use Manual Equipment** ☐ **Substitute Energy Source** ☐ **Nothing** ☐ **Other (please specify)** ☐
……….

30. What do you use to substitute for electricity? **Generator** ☐ **Gas** ☐ **Firewood/Charcoal** ☐ **Solar** ☐ **Other (please specify)** ☐

……………………………………………………………………………………………………
……………………………………………………..

31. Is the use of the substitute in **29** above more expensive than electricity? **Yes** ☐ **No** ☐

32. Does the use of alternative energy source increase operational cost? **Yes** ☐
No ☐

33. If **YES** above **(32),** by how much does the alternative energy source increased operational costs as a percentage **%………….**

34. Does load shedding caused a decline in output of business? **Yes** ☐ **No** ☐ **Insignificant** ☐ **Other (please specify)** ☐

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35. If **YES** above **(34),** does load shedding led to a decline in monthly income from enterprise**?**
Yes ☐ **No** ☐ **Insignificant** ☐ **Other (please specify)** ☐

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36. If **YES** above **(35),** what actions or measures do you take to deal with the decline in monthly income? **Increase price of products or service** ☐ **Cut down number of workers** ☐ **work over time when power is back** ☐ **Diversify income generating projects** ☐ **Other (please specify)** ☐ **…………………………………………………………………**

37. What other problems do power shortages created for your enterprise?

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38. What do you think is behind these power outages?

……………………………………………………………………………………………………
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Role of institutions

39. Is your business registered or acknowledged by anybody or institution? **Yes** ☐ **No** ☐

40. If **YES** above **(39),** which institution/body?

……………………………………………………………………………………………………
……………………………………………………..

41. Do you face any problems from any authorities or other people when running your business?
Yes ☐ No ☐

42. If **YES** above **(41),** which institution/body?

……………………………………………………………………………………………………
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43. What type of problems do you face from them?

……………………………………………………………………………………………………
…………………………………………………

44. Do you receive any assistance from government or any institution? Yes ☐

No ☐

45. If **YES above (44),** what type of assistance?

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46. What other assistance do you require for authorities and institutions?

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Other Comments or Notes

47. Please share any comments or views you may feel would help the survey.

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THANK YOU FOR YOUR TIME!!!!!!

Appendix F: Interview Guide for the Meteorological Services Department

Interview Guide for the Meteorological Services Department.
University of the Witwatersrand

Faculty of Science

School of Geography, Archaeology and Environmental Studies

Research Topic:

Perspectives on the Impacts of Climate Change and Energy Security on Urban Livelihoods of Poor Households in Harare, Zimbabwe.

Objective: *To get an understanding on the broad climatic trends in Zimbabwe.*

Interview Process

Open – ended questions will be used and wherever necessary additional probing questions will be asked for clarity sake.

I. Demographic Information.

a. Could you please state your position in the organization?

b. What are your responsibilities in this organization?

c. How long have you worked in your current position?

d. Have you worked for another organization before joining your current employers?

II. Insights on the climatic trends in Zimbabwe.

a. Do you believe that climate change is happening in Zimbabwe?

b. What climatic variables have significantly changed and are predicted to continue to change in Zimbabwe?

c. What climatic variables are predicted to impact on water resources the most in Zimbabwe?

d. What insights can you share on the historic and predicted climatic trends of the Zambezi River Basin?

III. The Role of Institutions in Climate Change issues in Zimbabwe.

a. How are climate change issues being addressed in Zimbabwe?

b. Who seems to be taking a leading role in addressing climate change issues in Zimbabwe?

c. Are there any strategies put in place to address climate change issues in Zimbabwe?

d. What role has this department played in addressing climate change issues in Zimbabwe?

e. Your department was part of the Southern Africa Regional Climate Services Workshop in Victoria Falls last year, what strategies were agreed upon to tackle climatic issues in the region?

Appendix G: Interview Guide for the Ministry of Environment, Water and Climate

Interview Guide for the Ministry of Environment, Water and Climate.

University of the Witwatersrand

Faculty of Science

School of Geography, Archaeology and Environmental Studies

Research Topic:

Perspectives on the Impacts of Climate Change and Energy Security on Urban Livelihoods of Poor Households in Harare, Zimbabwe.

Objective: *To get an understanding on the broad climatic trends in Zimbabwe.*

Interview Process

Open – ended questions will be used and wherever necessary additional probing questions will be asked for clarity sake.

I. **Demographic Information.**
   a. Could you please state your position in the organization?
   b. What are your responsibilities in this organization?
   c. How long have you worked in your current position?
   d. Have you worked for another organization before joining your current employers?

II. **Insights on the climatic trends in Zimbabwe.**
   a. Do you believe that climate change is happening in Zimbabwe?
   b. What climatic variables have significantly changed and are predicted to continue to change in Zimbabwe?
   c. What climatic variables are predicted to impact on water resources the most in Zimbabwe?
   d. What insights can you share on the historic and predicted climatic trends of the Zambezi River Basin?

III. **The Role of Institutions in Climate Change issues in Zimbabwe.**

a. How are climate change issues being addressed in Zimbabwe?

b. Who seems to be taking a leading role in addressing climate change issues in Zimbabwe?

c. Are there any strategies put in place to address climate change issues in Zimbabwe?

d. What role has this department played in addressing climate change issues in Zimbabwe?

Appendix H: Interview Guide for Zimbabwe National Water Authority (ZINWA)

Interview Guide for the Zimbabwe National Water Authority (ZINWA)
University of the Witwatersrand

Faculty of Science

School of Geography, Archaeology and Environmental Studies

Research Topic:
Perspectives on the Impacts of Climate Change and Energy Security on Urban Livelihoods of Poor Households in Harare, Zimbabwe.

Objective: *To identify the impacts that climate change has had on water resources in the Zambezi and what climatic variables you have observed that will impacts on water resources.*

Interview Process

Open – ended questions will be used and wherever necessary additional probing questions will be asked for clarity sake.

I. Demographic Information.

a. Could you please state your position in the organization?

b. What are your responsibilities in this organization?

c. How long have you worked in your current position?

d. Have you worked for another organization before joining your current employers?

II Climatic trends on water resources

a. May you please give an overview of what your department is tasked with?

b. What climatic factors affect water resources in Zimbabwe?

c. Has your department noted any historic, present and future climate trends that could affect the Zambezi River's water resources?

d. How does your department manage water resources especially rivers given their transboundary nature?

III. Climatic trends of the Zambezi.

a. What climatic factors affect the Zambezi's water resources?

b. How is Zambezi river basin managed given its transboundary nature and competing water uses for that basin

c. Has your department noted any historic, present and future climate trends that could affect the Zambezi River's water resources?

d. Are you in a position to share this data for academic use only?

III. Hydropower generation on the Zambezi Basin.

a. What role does ZINWA play in the management of water use at Kariba dam?

b. What role does ZINWA play in water use allocation at Kariba?

c. What factors affect hydropower generation on the Zambezi?

d. What are the challenges of hydropower generation on the basin in a climate change scenario?

IV. Efforts to protect the water resource and provide energy security.

a. What is your perception on the impact of climate change on water resources and energy security in the region?

b. In your pursuit to purposefully and sustainably exploit the natural resources offered by Zimbabwe's vast water catchments like the Zambezi River, how do you intend to regulate sustainable water use and development in Zimbabwe.

c. In your view what role has government and relevant stakeholders played to secure and protect the water resources in Zimbabwe especially in a threatening climate change environment.

d. What are the future challenges associated with competing water needs in Zimbabwe and how do you propose they be managed?

Appendix I: Interview Guide for the Zambezi River Authority (ZRA)

Interview Guide for the Zambezi River Authority (ZRA)
University of the Witwatersrand

Faculty of Science

School of Geography, Archaeology and Environmental Studies

Research Topic:

Perspectives on the Impacts of Climate Change and Energy Security on Urban Livelihoods of Poor Households in Harare, Zimbabwe.

Objective: *To identify the impacts that climate change has had on water resources in the Zambezi and how they potentially affect hydropower generation of Kariba Power Station.*

Interview Process

Open – ended questions will be used and wherever necessary additional probing questions will be asked for clarity sake.

I. Demographic Information.

a. Could you please state your position in the organization?

b. What are your responsibilities in this organization?

c. How long have you worked in your current position?

d. Have you worked for another organization before joining your current employers?

II. Climatic trends of the Zambezi.

a. May you please give an overview of what you department is tasked with?

b. What climatic factors affect the Zambezi's water resources?

c. Has your department noted any historic, present and future climate trends that could affect the Zambezi River's water resources?

III. Hydropower generation on the Zambezi Basin.

e. What is the estimated hydropower generating potential of the Zambezi?

f. What factors affect hydropower generation on the Zambezi?

g. What are the challenges of hydropower generation on the basin in a climate change scenario?

h.

IV. Kariba Hydropower Station.

a. May you please give an overview of Kariba Dam Complex?

b. What factors affect hydropower generation of Kariba Power Station?

c. What historic climatic factors have affected Kariba Power Station's ability to generate electricity?

d. What are the future challenges of hydropower generation of Kariba Power Station?

V. Efforts to protect the water resource and provide energy security.

e. What is your perception on the impact of climate change on hydropower generation in the region?

f. In your pursuit to purposefully and sustainably exploit the natural resources offered by the Zambezi River, how do you intend to provide energy security for Zimbabwe and Zimbabwe from the electricity generated from Kariba Dam?

g. In your view what role has government and relevant stakeholders played to improve energy security especially from hydropower in a climate change scenario?

h. What are the future challenges of hydropower generation of Kariba Power Station?

Appendix J: Interview Guide for the Ministry of Energy and Power Development

Interview Guide for the Ministry of Energy and Power Development
University of the Witwatersrand

Faculty of Science

School of Geography, Archaeology and Environmental Studies

Research Topic:

Perspectives on the Impacts of Climate Change and Energy Security on Urban Livelihoods of Poor Households in Harare, Zimbabwe.

Objective: *To explore energy security in Zimbabwe and the bearing that climate change has on energy security.*

Interview Process

Open – ended questions will be used and wherever necessary additional probing questions will be asked for clarity sake.

I. Demographic Information.

a. Could you please state your position in the organization?
b. What are your responsibilities in this organization?
c. How long have you worked in your current position?
d. Have you worked for another organization before joining your current employers?

II. Zimbabwe's electricity structure.

a. May you please give an overview of the Department, including the various roles it plays in securing energy for Zimbabwe?
b. How much installed capacity does Zimbabwe have?
c. Does this meet demand?
d. How do you make up for the deficit?
e. Does the consumer bare additional electricity costs when you use the above strategy to make up for the deficit?

d. Which source of electricity contributes the most to the national grid?

III. Hydropower Generation.

a. How many hydropower plants contribute to the national grid?
b. What challenges have these hydropower plants faced in their efforts to contribute to the national grid making special reference to Kariba Power Station?
c. How have climatic factors historically affected power generations by hydropower plants especially Kariba Station?
d. What are your views on climate change impacting on hydropower generation at Kariba Power Station?
e. Are there any concerns from your department of future setbacks that are climate related that may impact on Kariba Power Station's ability to substantially contribute to the national grid?
f. If so, what are the strategies employed to tackle them?

IV. Energy Security of Zimbabwe

a. Would you say Zimbabwe is energy secure?
b. Does climate change affect Zimbabwe's energy security?
c. What strategies have been put to improve energy security in Zimbabwe?
d. In your view what role has government and relevant stakeholders played to improve energy security especially from hydropower in a climate change scenario?
e. Has the government looked at renewables as alternatives to improve energy security? If so, what is has been implemented and what is in the pipeline?

Appendix K: Interview Guide for the Zimbabwe Electricity Supply Authority (ZESA)

Interview Guide for Zimbabwe Electricity Supply Authority (ZESA)
University of the Witwatersrand

Faculty of Science

School of Geography, Archaeology and Environmental Studies

Research Topic:

Perspectives on the Impacts of Climate Change and Energy Security on Urban Livelihoods of Poor Households in Harare, Zimbabwe.

Objective: *To explore energy security in Zimbabwe and the bearing that climate change has on energy security.*

Interview Process

Open – ended questions will be used and wherever necessary additional probing questions will be asked for clarity sake.

I. Demographic Information.

a. Could you please state your position in the organization?
b. What are your responsibilities in this organization?
c. How long have you worked in your current position?
d. Have you worked for another organization before joining your current employers?

II. Zimbabwe's electricity structure.

f. May you please give an overview of ZESA holdings, including the various roles it plays in securing energy for Zimbabwe?
g. How much installed capacity does Zimbabwe have?
h. Does this meet demand?
i. How do you make up for the deficit?
j. Does the consumer bare additional electricity costs when you use the above strategy to make up for the deficit?

d. Which source of electricity contributes the most to the national grid?

III. Hydropower Generation.

a. How many hydropower plants contribute to the national grid?
b. What challenges have these hydropower plants faced in their efforts to contribute to the national grid making special reference to Kariba Power Station?
c. How have climatic factors historically affected power generations by hydropower plants especially Kariba Station?
d. What are your views on climate change impacting on hydropower generation at Kariba Power Station?
e. Are there any concerns from your department of future setbacks that are climate related that may impact on Kariba Power Station's ability to substantially contribute to the national grid?
f. If so, what are the strategies employed to tackle them?

IV. Energy Security of Zimbabwe

f. Would you say Zimbabwe is energy secure?
g. Does climate change affect Zimbabwe's energy security?
h. What strategies have been put to improve energy security in Zimbabwe?
i. In your view what role has government and relevant stakeholders played to improve energy security especially from hydropower in a climate change scenario?

Appendix L: Interview Guide for the Department of Small and Medium Enterprises and Cooperative Development

Interview Guide for the Department of Small and Medium Enterprises and Cooperative Development
University of the Witwatersrand

Faculty of Science

School of Geography, Archaeology and Environmental Studies

Research Topic:

Perspectives on the Impacts of Climate Change and Energy Security on Urban Livelihoods of Poor Households in Harare, Zimbabwe.

Objective: *To identify the institutional and policy framework in Zimbabwe and how its supports the informal sector.*

Interview Process

Open – ended questions will be used and wherever necessary additional probing questions will be asked for clarity sake.

I. Demographic Information.

a. Could you please state your position in the organization?
b. What are your responsibilities in this organization?
c. How long have you worked in your current position?
d. Have you worked for another organization before joining your current employers?

II. The informal sector of Zimbabwe.

a. May you please give a brief background of the Ministry and the work it does?
b. What criteria do people in Micro, Small and Medium Enterprises (MSME) have to meet if they are to get assistance from your ministry?
c. What type of assistance do you give them?
d. Are there packages tailor made to assist women in MSMEs?
e. Do you recognize home-based informal micro-enterprises?

f. What are the characteristics of these home-based informal micro-enterprises?

III. Challenges of the informal sector of Zimbabwe.

a. What challenges does the informal sector face in accessing assistance form your department?
b. How do you handle issues of registration and taxation for members in the informal economy that want to get assistance from you?
c. What type of assistance do you give to home-based micro-enterprises?
d. Are the mechanisms put in place to monitor the effects of electricity shortages on the informal sector?
e. In your pursuit to provide assistance to Micro, Small and Medium Enterprises (MSMEs) and Community development, how do you intend to promote sustainable development and protection of livelihoods strategies of women in home-based informal work?

Appendix M: Ethics Clearance Certificate

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Ried

CLEARANCE CERTIFICATE	PROTOCOL NUMBER: H17/08/28
PROJECT TITLE	Perspectives on the impact of climate change and energy security on urban livelihoods
INVESTIGATOR(S)	Mrs M Ried
SCHOOL/DEPARTMENT	Geography, Archaeology and Environmental Studies/
DATE CONSIDERED	18 August 2017
DECISION OF THE COMMITTEE	Approved
EXPIRY DATE	01 November 2020

DATE 02 November 2017 CHAIRPERSON (signature)
(Professor J Knight)

cc: Supervisor : Professor D Simatele

DECLARATION OF INVESTIGATOR(S)

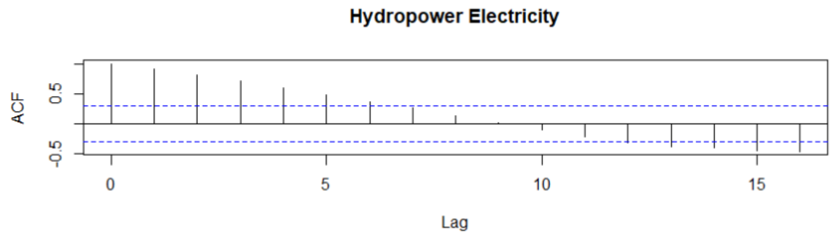
To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University. Unreported changes to the application may invalidate the clearance given by the HREC (Non-Medical)

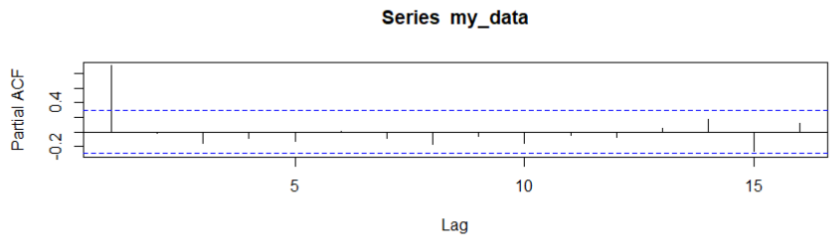
I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to completion of a yearly progress report.**

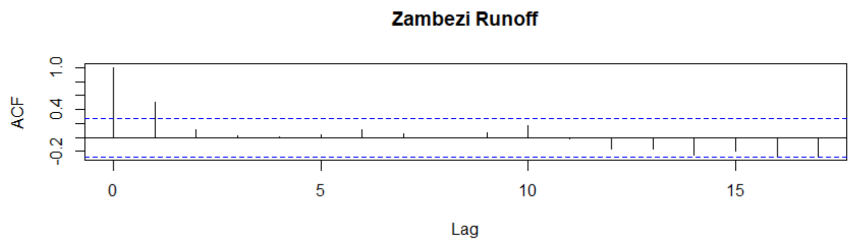
_______________ ____/____/____
Signature Date

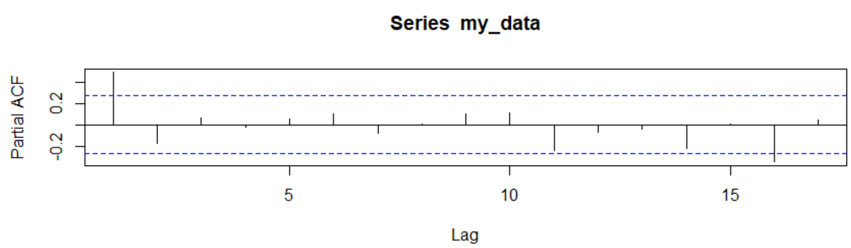
PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

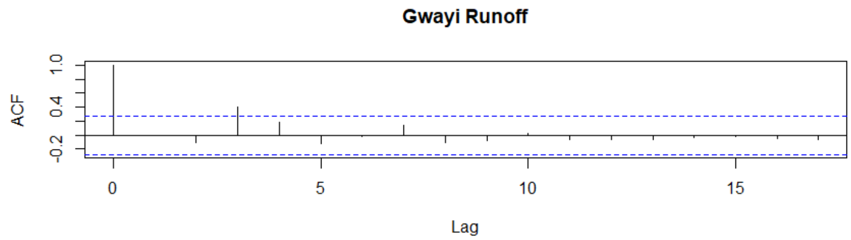
Appendix N: Autocorrelation results plots for temperature, precipitation, runoff and hydropower generation in the Kariba sub-basin







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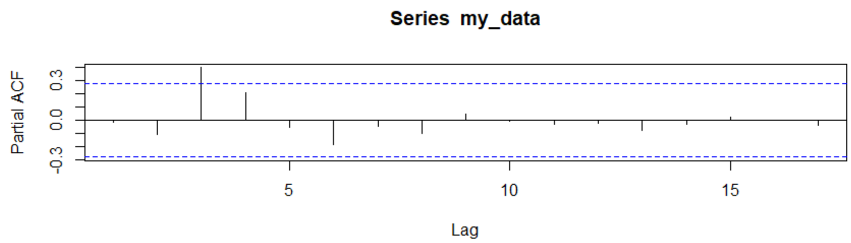
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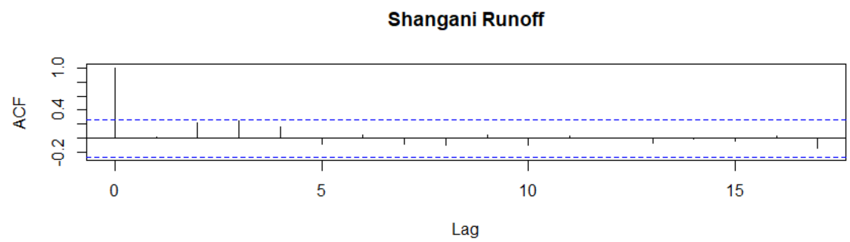
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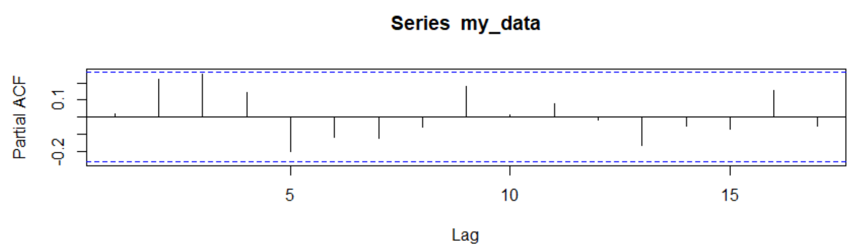
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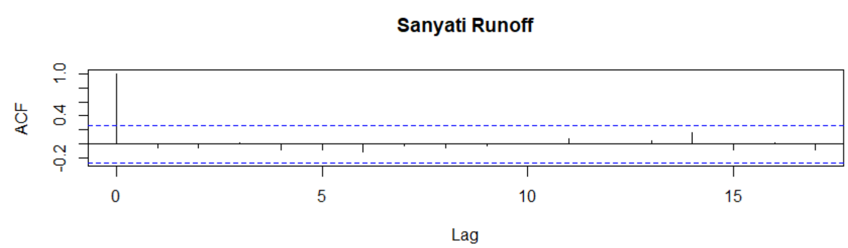
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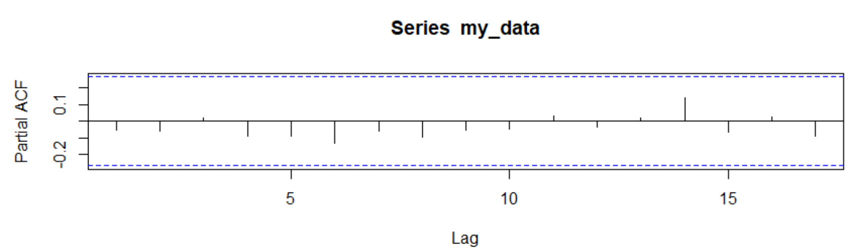
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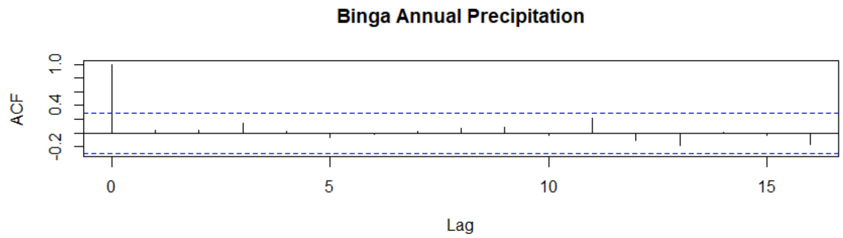
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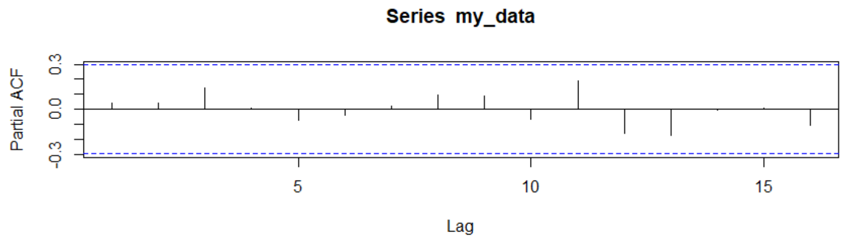
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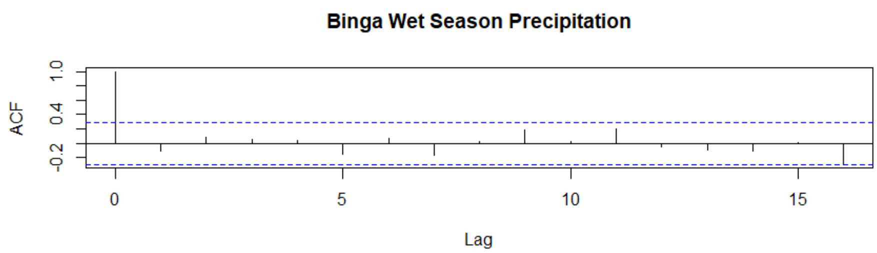
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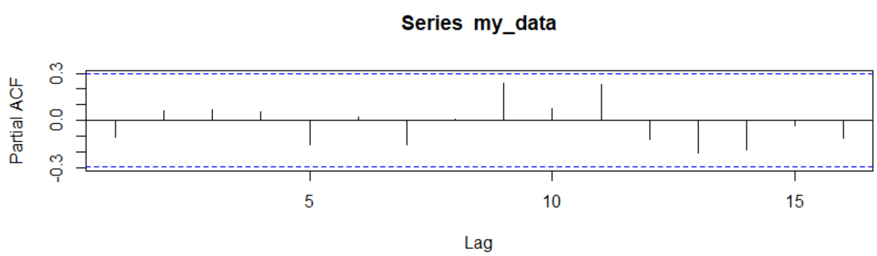
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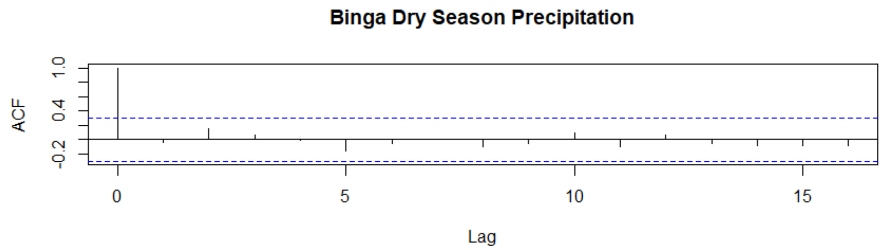
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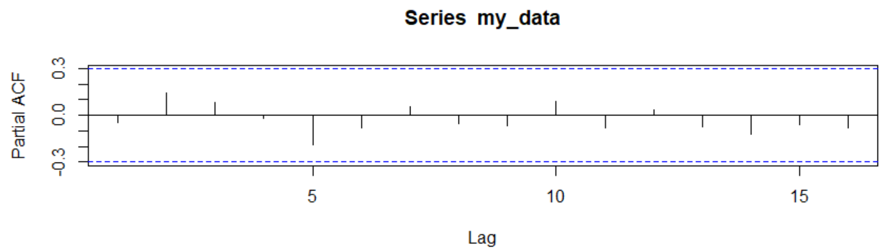
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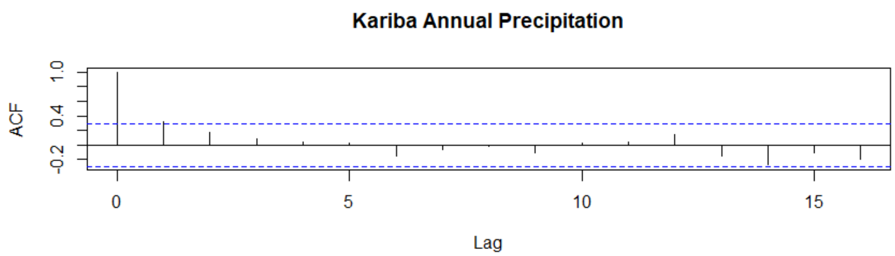
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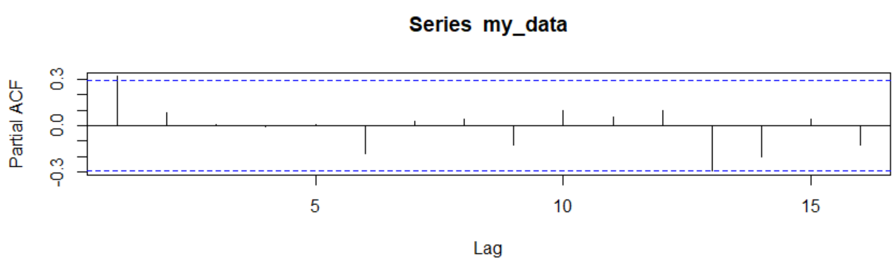
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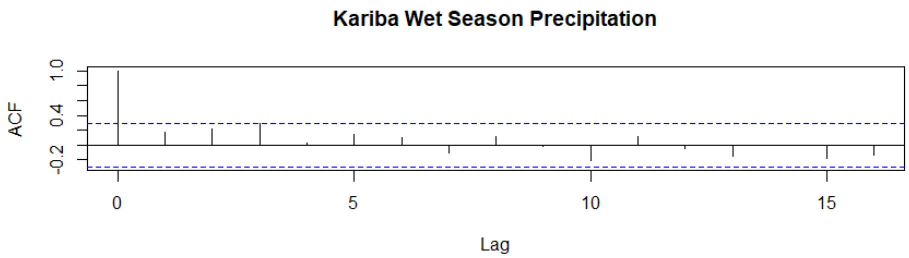
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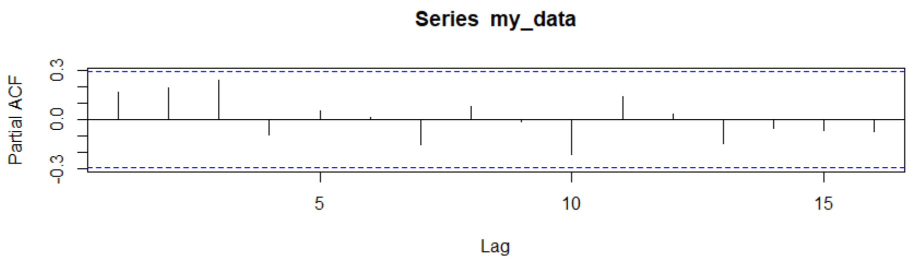
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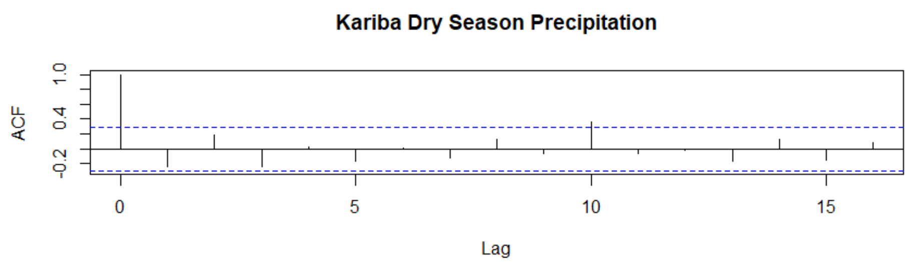
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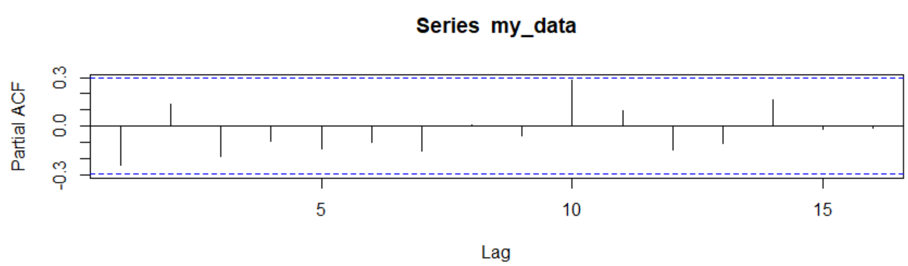
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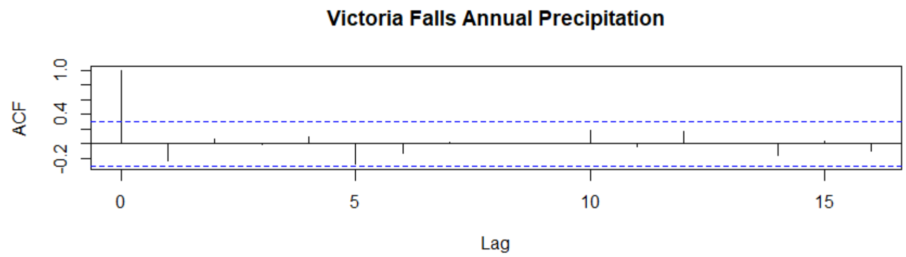
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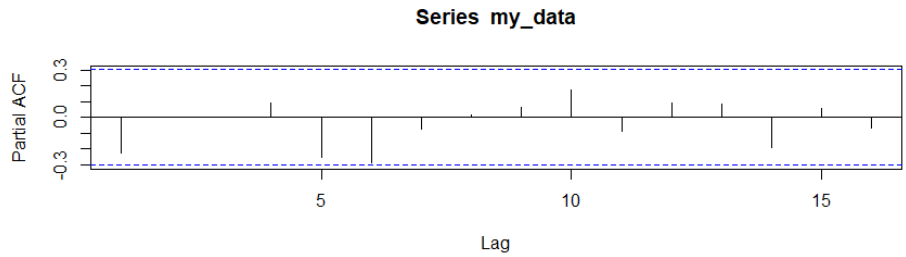
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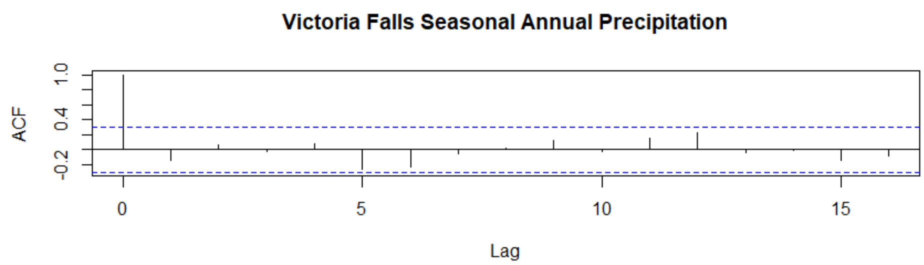
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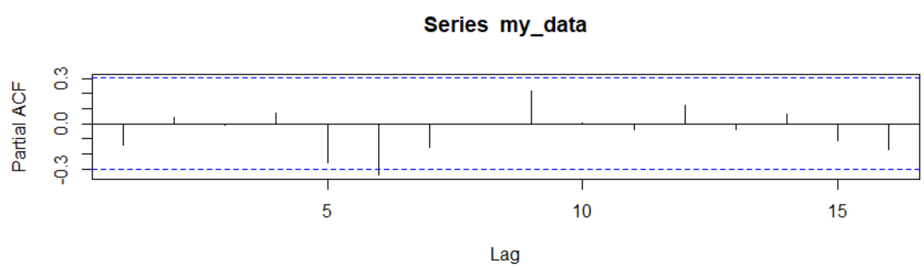
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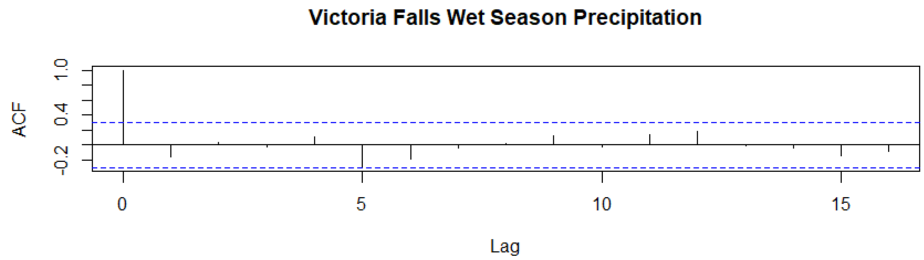
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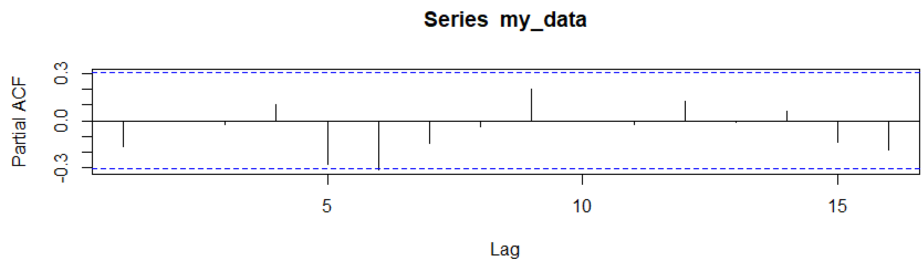
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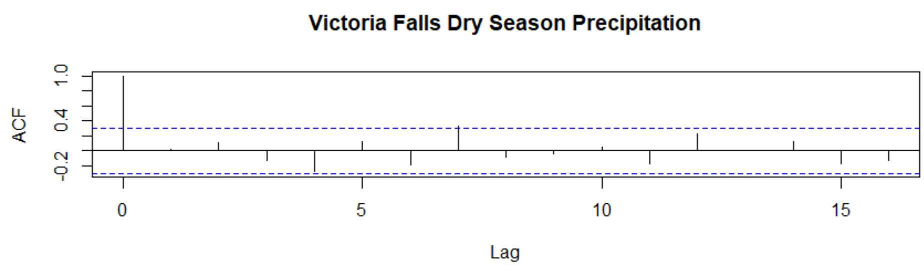
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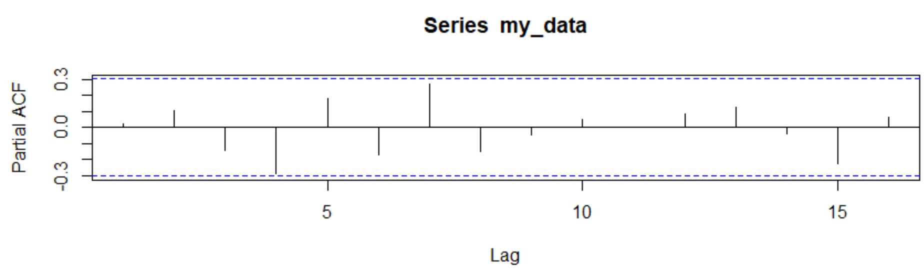
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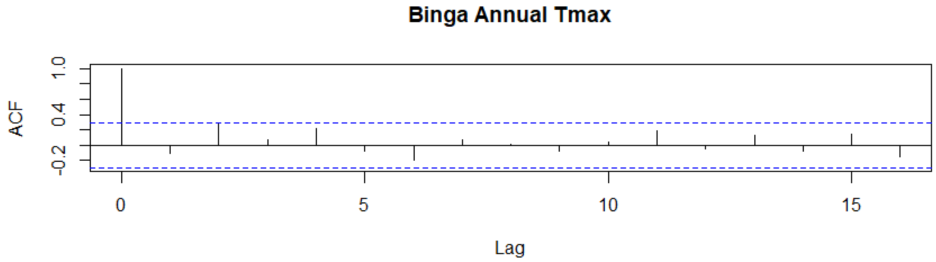
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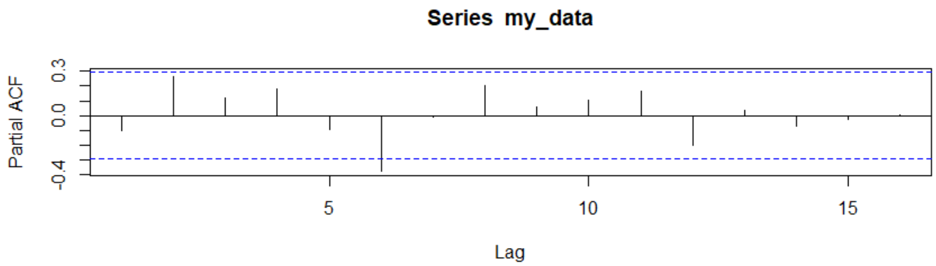
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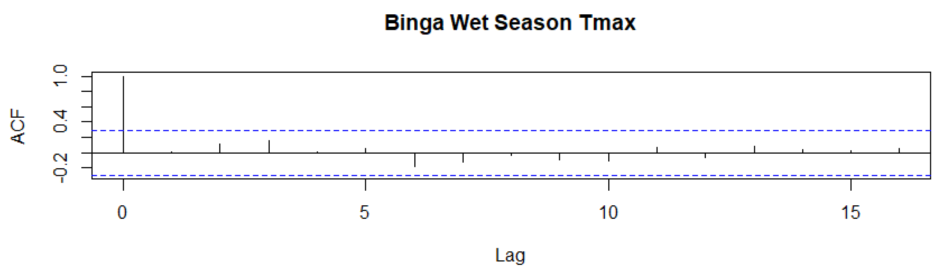
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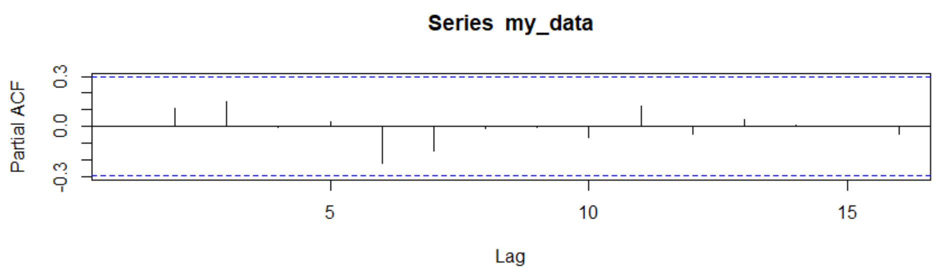
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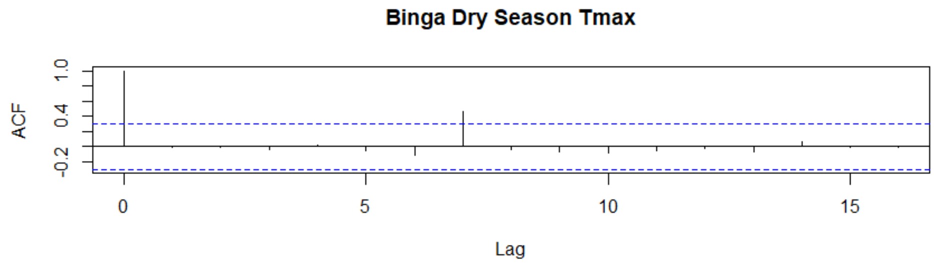
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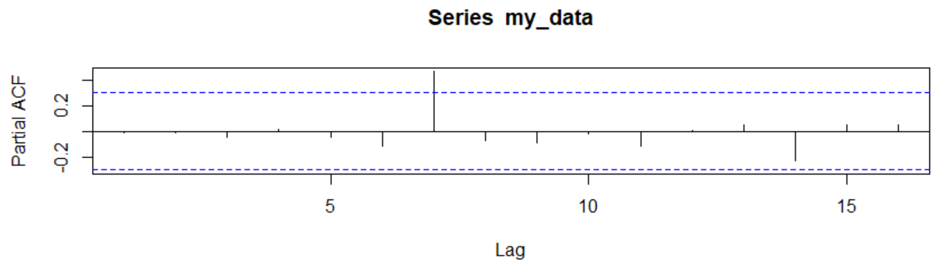
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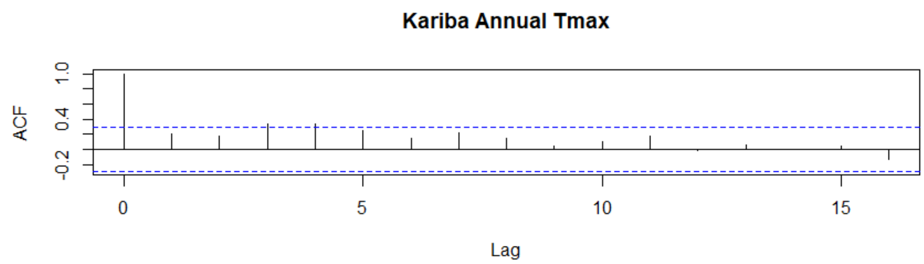
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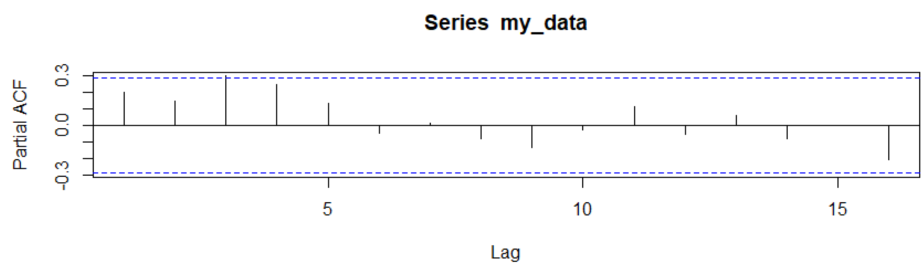
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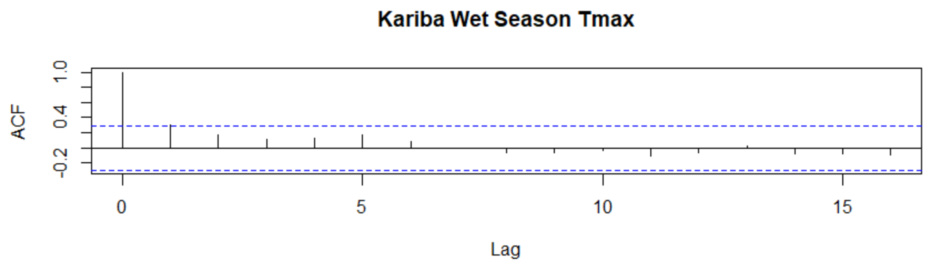
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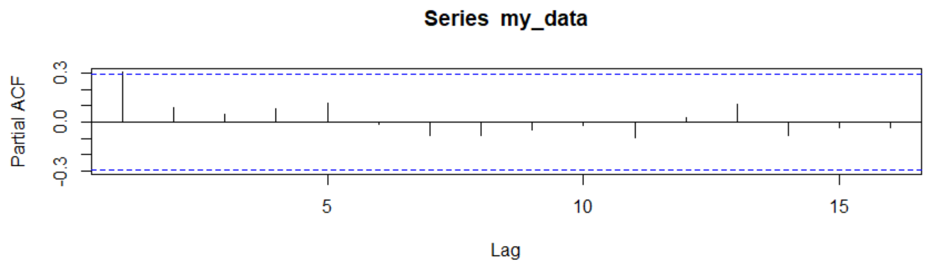
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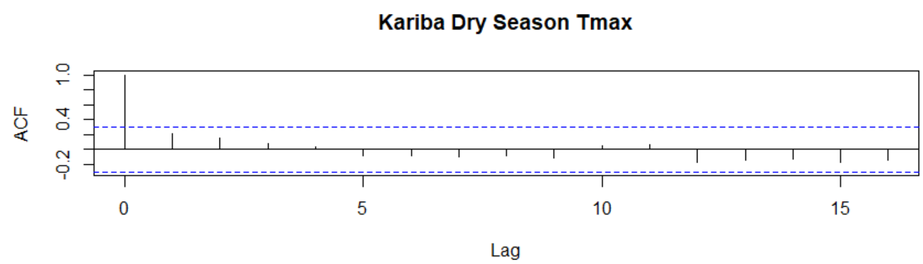
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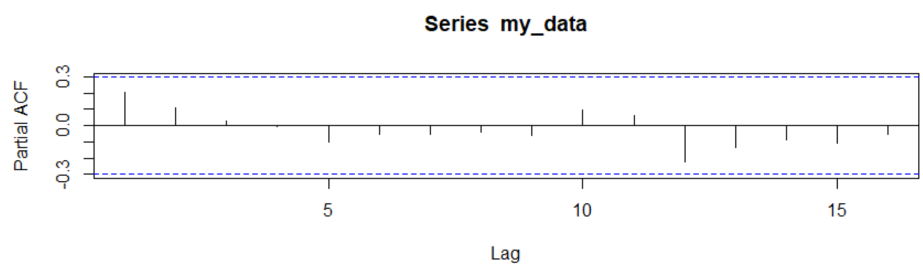
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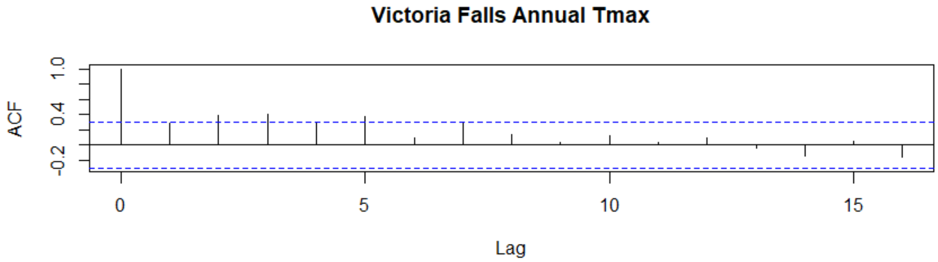
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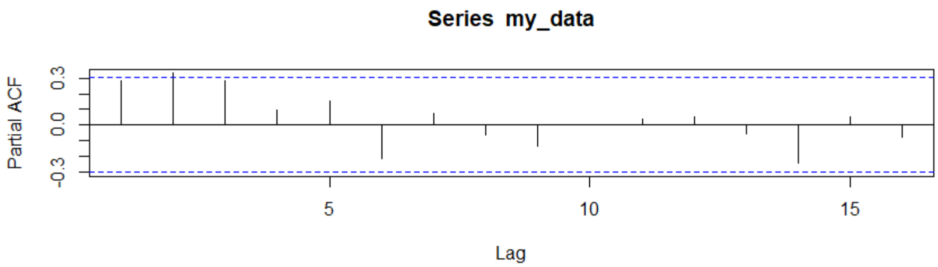
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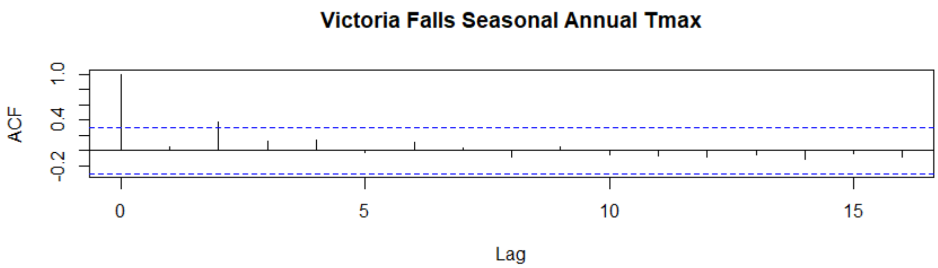
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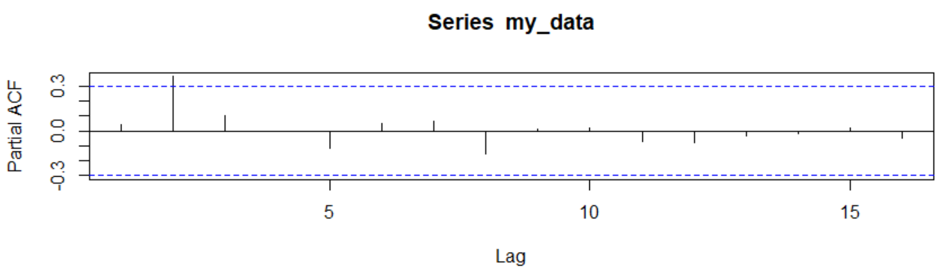
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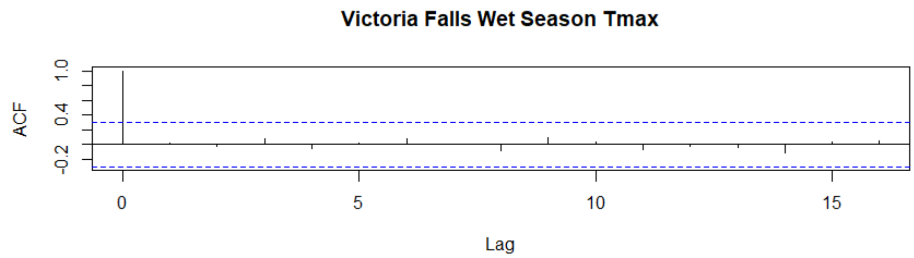
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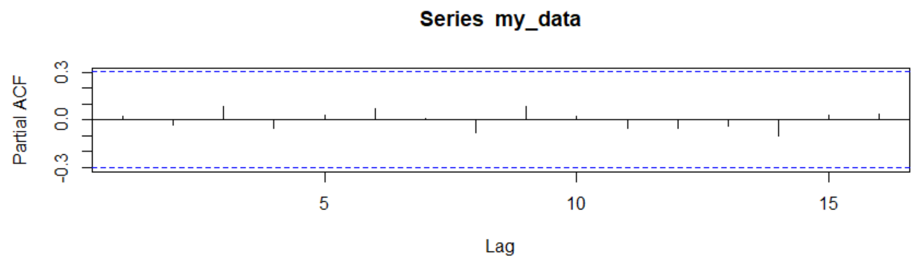
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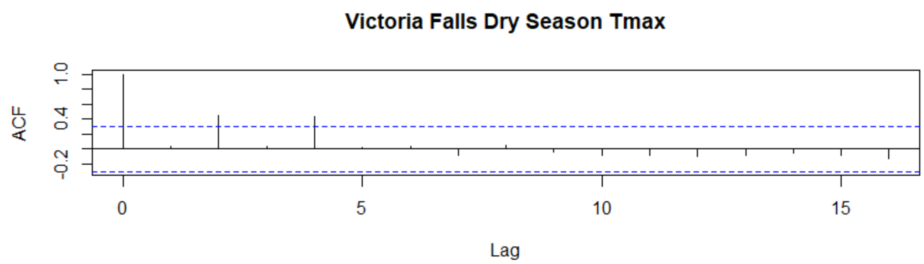
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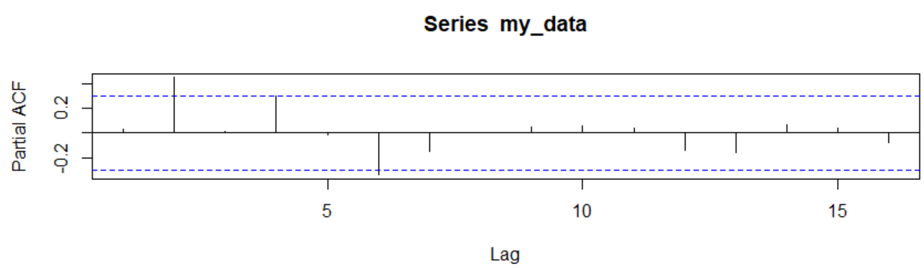
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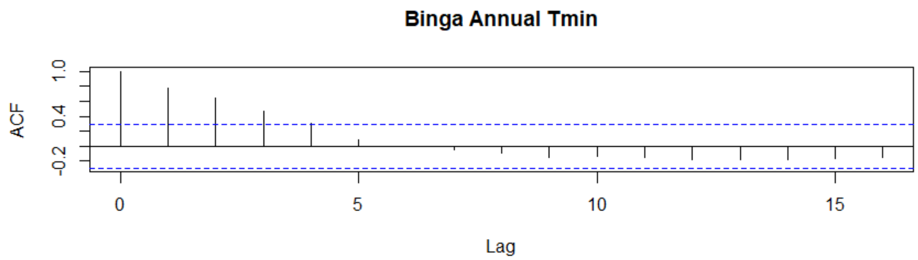
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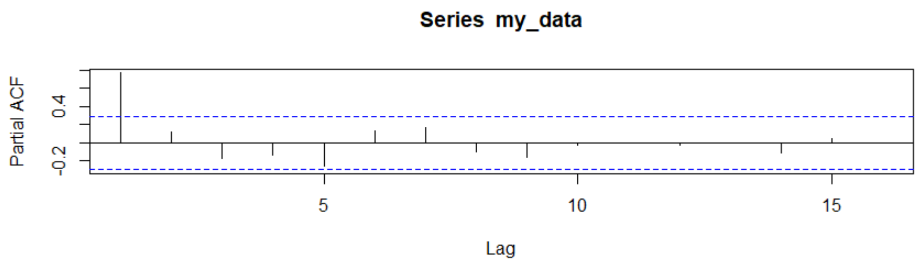
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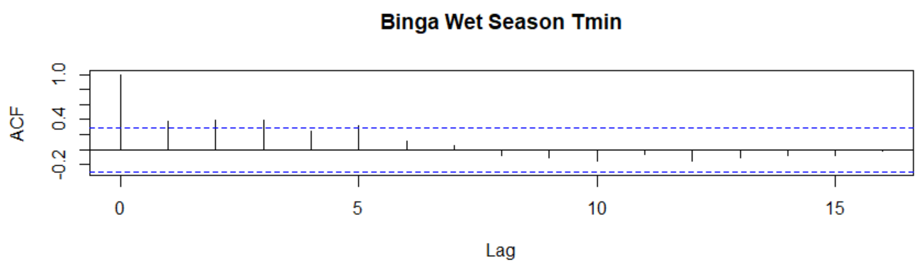
Binga Wet Season Tmin
ACF
-0.2
0.4
1.0
0
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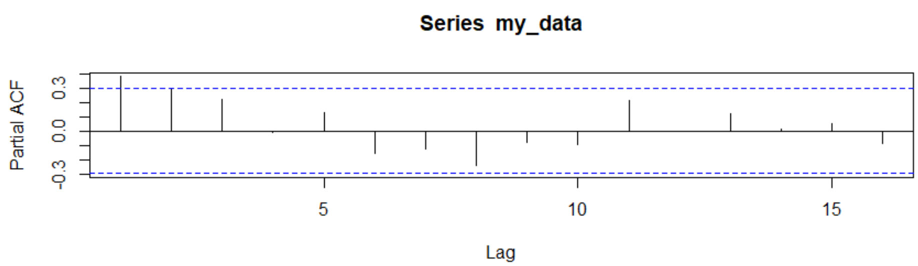
Lag


Series my_data
Partial ACF
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0.3
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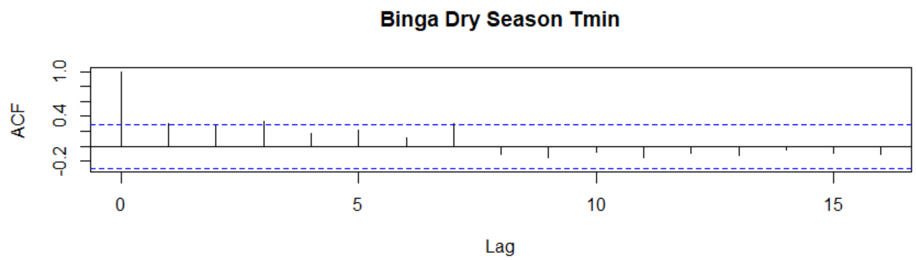
Lag


Binga Dry Season Tmin
ACF
1.0
0.4
-0.2
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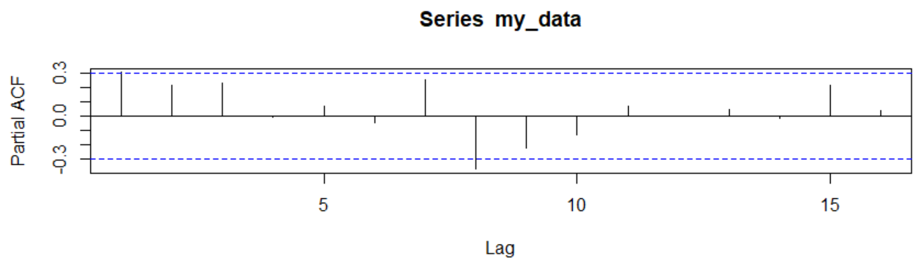
Lag


Series my_data
Partial ACF
0.3
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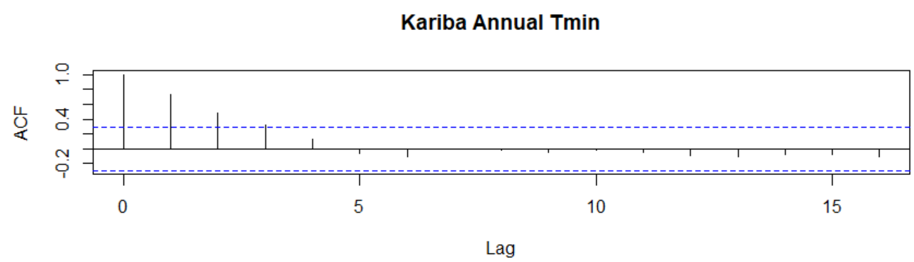
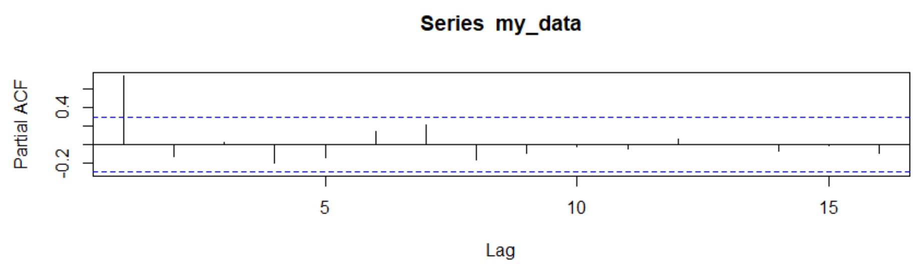
Lag


Kariba Annual Tmin
ACF
1.0
0.4
-0.2
0
5
10
15
Lag


Series my_data
Partial ACF
0.4
-0.2
5
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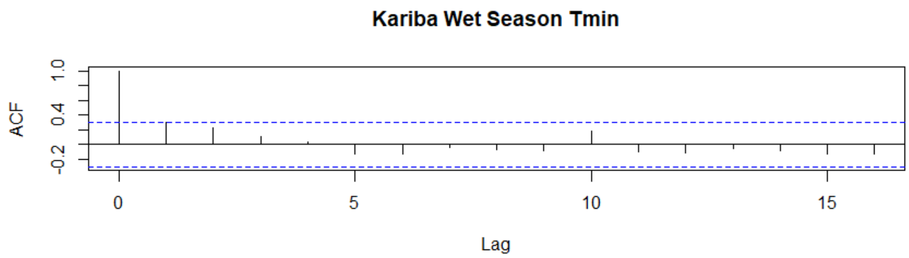
Lag


Kariba Wet Season Tmin
ACF
1.0
0.4
-0.2
0
5
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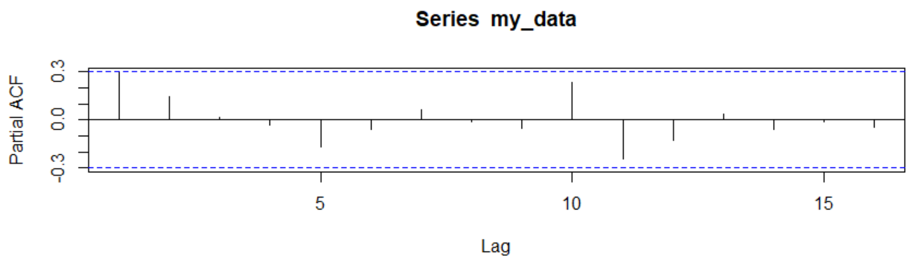
15
Lag


Series my_data
Partial ACF
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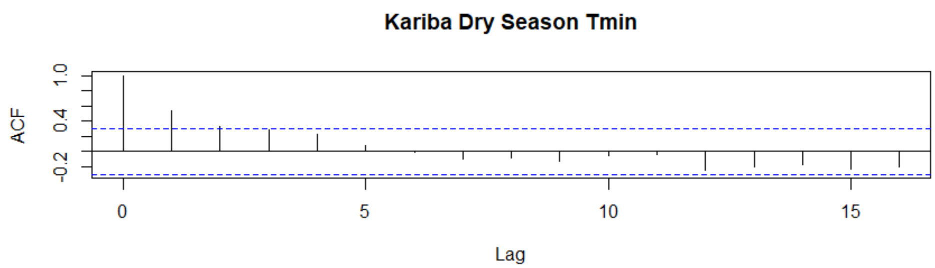
Lag


Kariba Dry Season Tmin
ACF
1.0
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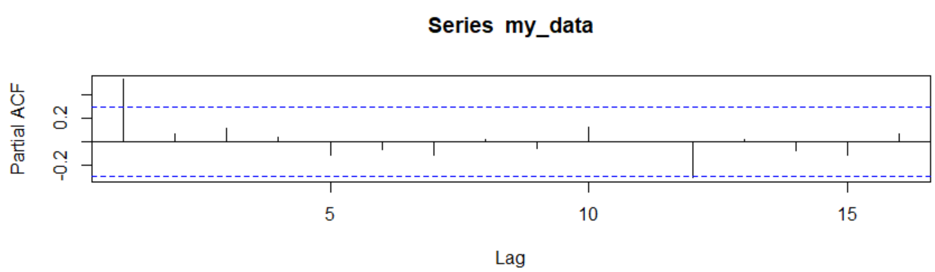
Lag


Series my_data
Partial ACF
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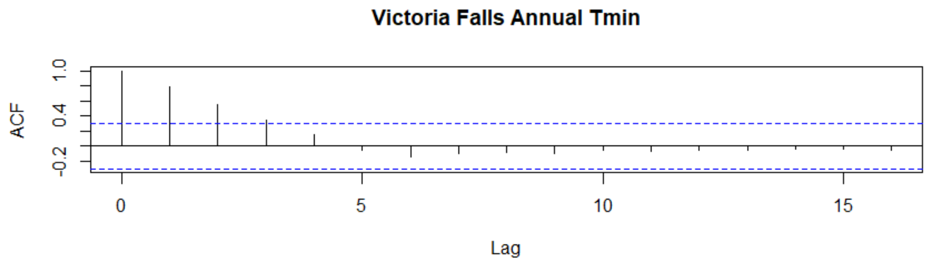
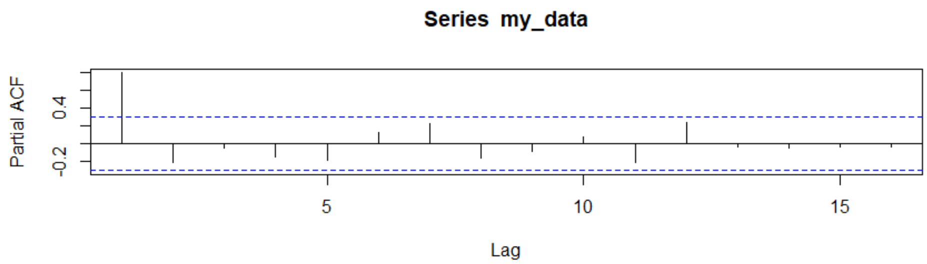
Lag


Victoria Falls Annual Tmin
ACF
-0.2
0.4
1.0
0
5
10
15
Lag


Series my_data
Partial ACF
-0.2
0.4
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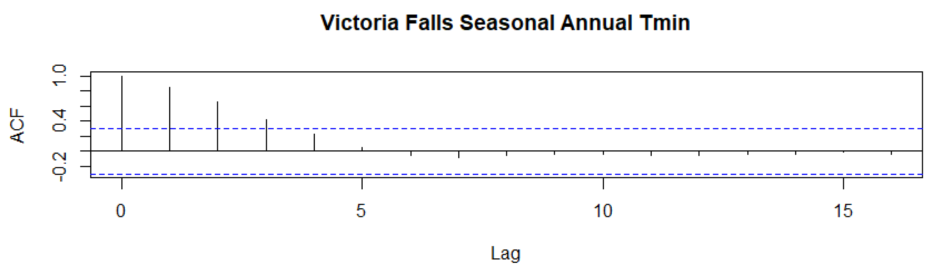
Lag


Victoria Falls Seasonal Annual Tmin
ACF
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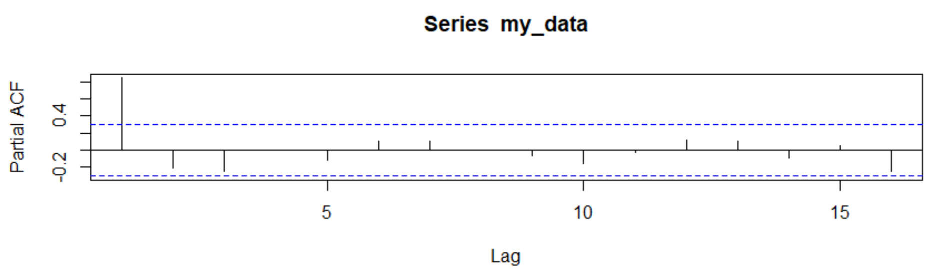
0.4
1.0
0
5
10
15
Lag


Series my_data
Partial ACF
-0.2
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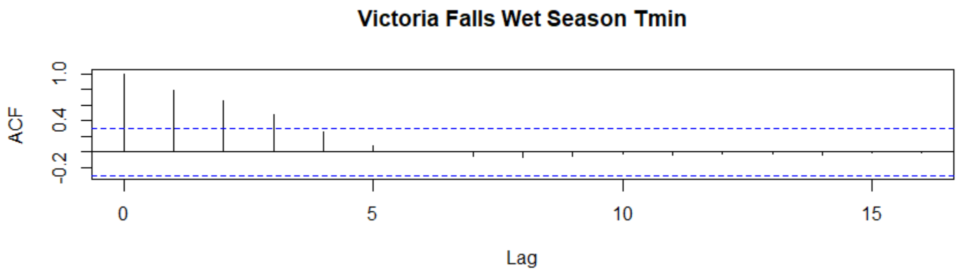
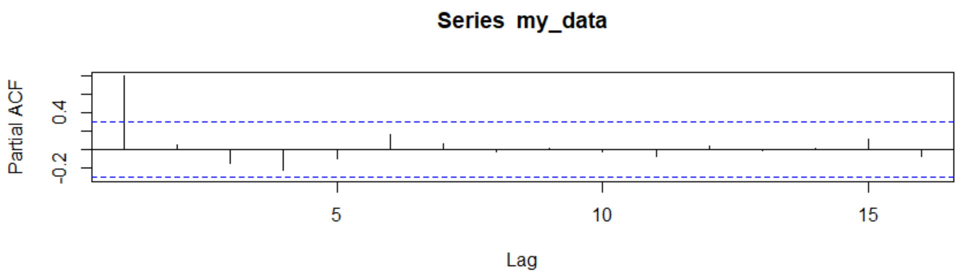
Lag


Victoria Falls Wet Season Tmin
ACF
-0.2
0.4
1.0
0
5
10
15
Lag


Series my_data
Partial ACF
-0.2
0.4
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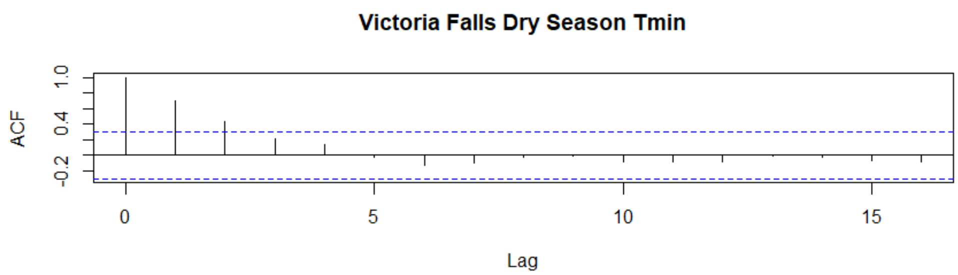
Lag


Victoria Falls Dry Season Tmin
ACF
-0.2
0.4
1.0
0
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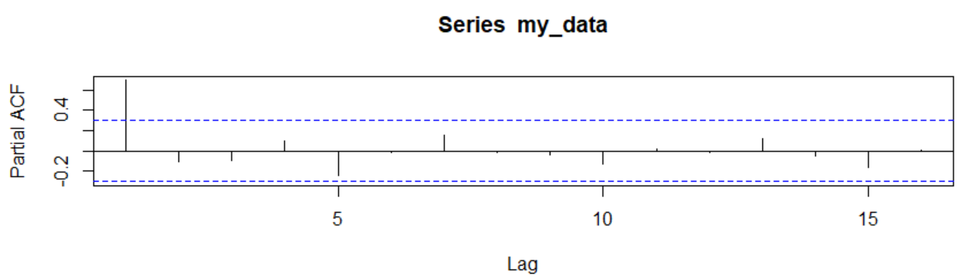
Lag


Series my_data
Partial ACF
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0.4
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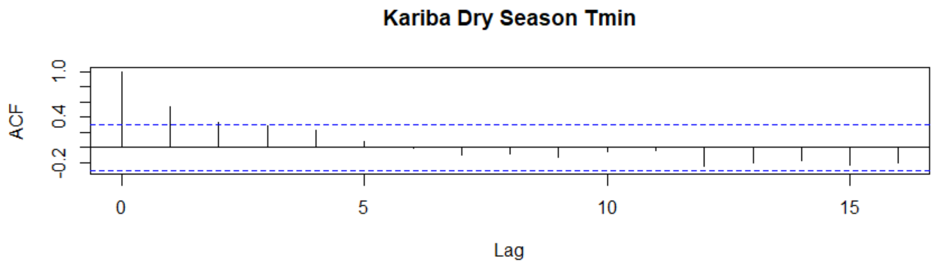
Lag


Kariba Dry Season Tmin
ACF
-0.2
0.4
1.0
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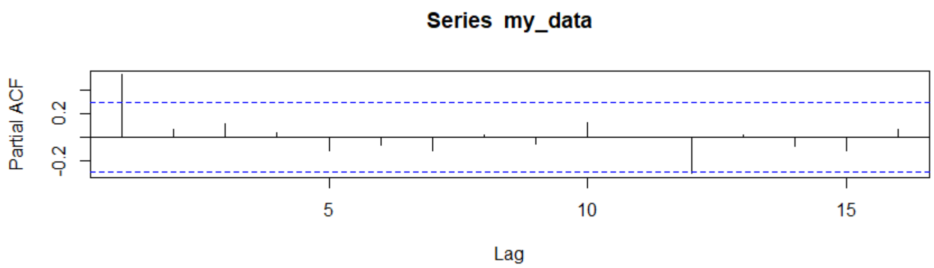
Lag


Series my_data
Partial ACF
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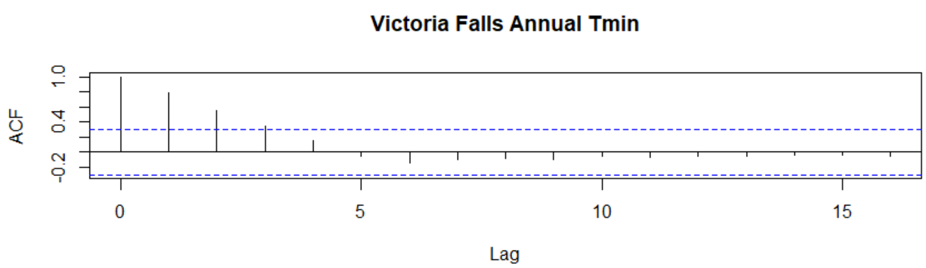
Lag


Victoria Falls Annual Tmin
ACF
-0.2
0.4
1.0
0
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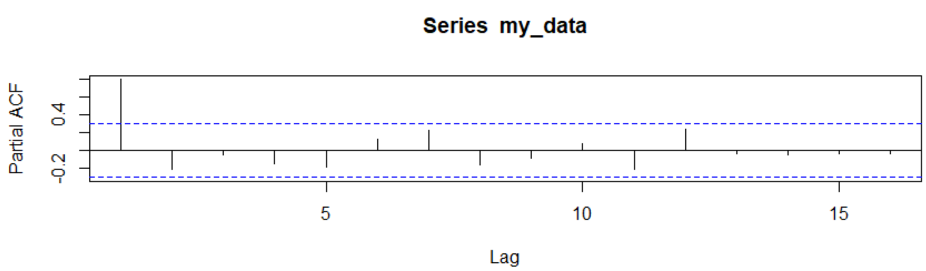
15
Lag


Series my_data
Partial ACF
-0.2
0.4
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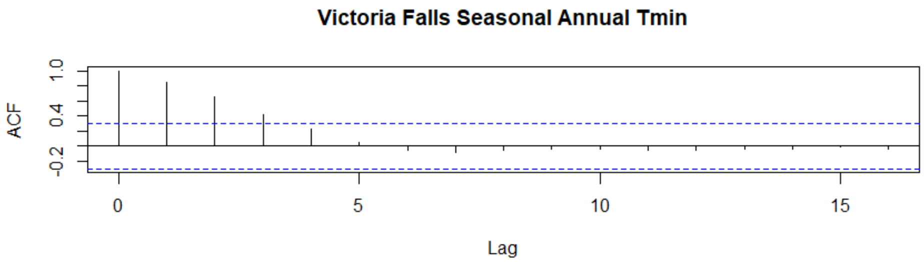
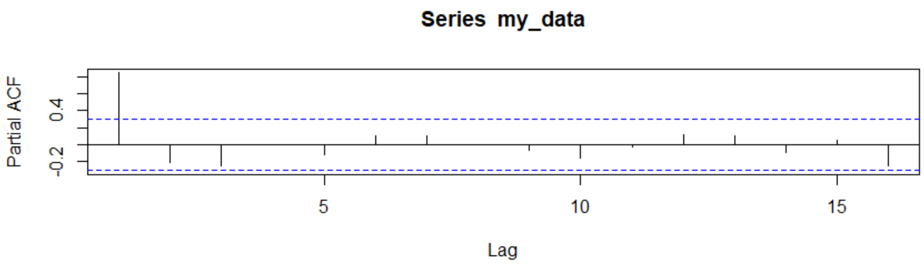
Lag


Victoria Falls Seasonal Annual Tmin
ACF
-0.2
0.4
1.0
0
5
10
15
Lag


Series my_data
Partial ACF
-0.2
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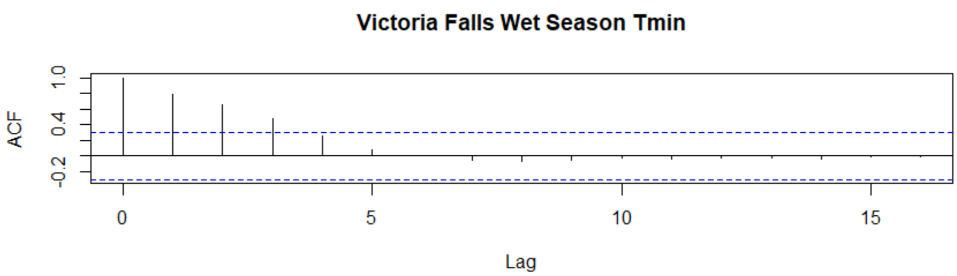
Lag


Victoria Falls Wet Season Tmin
ACF
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0.4
1.0
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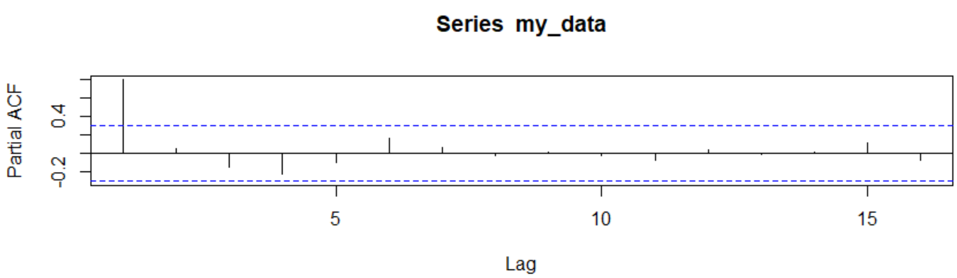
Lag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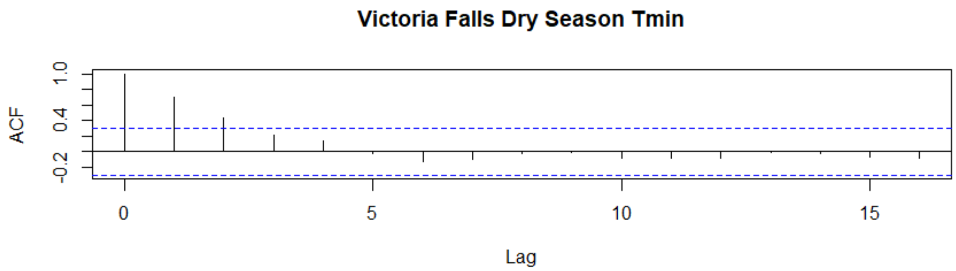
Victoria Falls Dry Season Tmin
ACF
1.0
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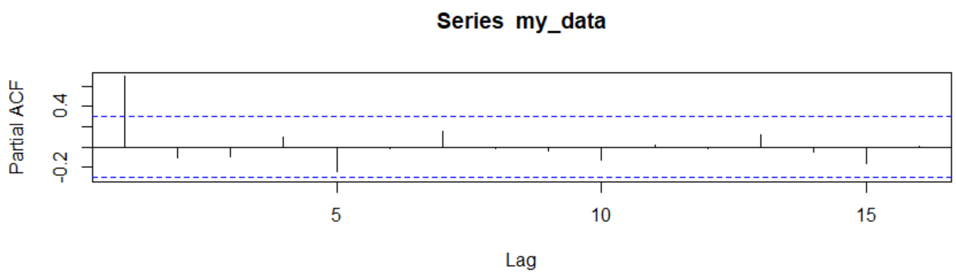
Lag


Series my_data
Partial ACF
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Lag