CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Climate variability has been one of the major issues of the 21st century. In fact, its importance keeps on increasing with the realization that its impacts cut across all sectors of a country's economy. Hence it should not only be looked at just as an environmental issue but also a developmental issue. Presently the scientific consensus on climate change is that human activity is very likely the cause for the increase in global average temperatures over the past several decades (IPCC, 2001) . However, it is important to note that the subject of climate change is a complex one with a lot of uncertainties and a lot of researches are still being conducted among both the proponents and critics of climate change. The increased Green House Gases (GHGs) in the atmosphere has been cause for increased global climatic variations. Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 A.D and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. The global increases in carbon dioxide concentration are due primarily to fossil fuel use and land use change, while those of methane and nitrous oxide are primarily due to agriculture (Ibid).

In Zambia, recent decades have seen an increase in intensity and frequency of floods and droughts (GRZ, 2010). Currently, global temperatures are estimated to be about 0.8ºC above the preindustrial levels (The World Bank, 2010). In fact, the six warmest years in recent decades in Southern Africa have all occurred since 1980 (Yanda and Mubaya, 2011). For Africa, there has been a warming of approximately 0.7ºC across the continent in the 20th century (Yanda and Mubaya, 2011). While this warming trend appears to be the same over the continent, it's not always uniform. Tropical forests have been recording decadal warming rates of 0.29ºC (Malhi and Wright, 2004) with South Africa having a rate ranging from 0.1ºC to 0.3ºC (Kruger and Shongwe, 2004) . Southern Africa has been reported as having a an annual rate of 0.05ºC and this was observed during the present century (Hulme, 1996; Jain 2007) . A mean temperature rise of 1.5ºC in Southern Africa is expected and this coupled with increased rainfall variability and food insecurity (Hulme 1996). On a local level, disagreements on the rate of temperature increase have been apparent with some studies reporting an increase of 0.6ºC per decade (World Bank, 2006; Jain, 2007) while others suggesting a 0.32ºC temperature increase per decade (Shitumbanuma, 2008). Hence, the need for a study that will establish the rates of temperature increase at a local level. This is important because climate, climate change and vulnerabilities differ from one region to another, and as such, regionally and locally specific climate information is essential for adaptation (Conway, 2009; WCC-3, 2009).

Evidence of inter-annual climate variability in some parts of Africa has been observed. For example, observations in Western Africa indicates that there has been a decrease in the mean annual rainfall of up to 30% to 40% since the end of the 1960s (Chappell and Agnew, 2004). Furthermore, there was a decrease in mean annual rainfall in the tropical rain forest zone of 4% in West Africa, 3% in North Congo and 2% in South Congo for the period 1960 to 1999 (Malhi and Wright, 2004). On the other hand significant rainfall increase has been recorded along the Guinean Coast in the last 30 years (Yanda and Mubaya, 2011) as there has been in East and Central Africa (IPCC, 2001). However, there are some regions in Southern Africa where no long term trends in rainfall have been noted (Boko et al. 2007) .

Zambia has been experiencing an increase in the frequency and intensity of droughts and floods. According to Usman and Reason (2004), this situation is to be expected as some parts of Southern Africa which includes Angola, Zambia, Namibia, Mozambique and Malawi are expected to record significant increases in heavy rainfall events. On the other hand rainfall variability has manifested itself in higher rainfall anomalies and the more intense and widespread droughts that have been reported (e.g. Boko et al. 2007; Fauchereau et al. 2003; Yanda and Mubaya, 2011). Recent studies indicate that temperatures in Zambia have been increasing especially over the last three decades (GRZ, 2007; World Bank, 2006; Jain, 2007; Ngoma, 2008, Shitumbanuma, 2008) while the country has experienced an increase in the frequency and intensity of droughts and floods. In the case of Southern Zambia, it has been a case of frequent and intense droughts, although some areas also experience floods. Sichingabula (1995) reported that the climate of Zambia has been characterized by epic dry and wet periods. Rainfall records show that Southern Zambia experienced below and above average rainfall in the periods 1886 – 1925 and 1926-1970, respectively (Sichingabula, 1998). Zambia experienced droughts in the seasons 1916/17, 1924/25, 1949/50, 1983/84, 1987/88, 1991/92, 1994/95 and 1997/98 (Sichingabula 1998) . Occurrence of droughts has also been reported in the 2001/03 and 2004/05 seasons (Lekprichakul, 2008). These events are also understood to be closely related to El Niño and the Southern Oscillation phenomenon which affects Eastern and Southern Africa.

These extreme climatic events have had negative impacts not only on small-scale agriculture but also on the Zambian economy at large. The economic impacts of droughts on Zambian are evident as Lekprichakul (2008) reports that the 2004/05 droughts led to a 60% loss of yields to maize. This had an effect even on the next agricultural year when maize production recorded a drastic decrease of about 233,234 tons or about 22% from the previous year. CSO (2006) post-harvest report recorded that in the 2003/04 growing season, 1,134,319 tons of maize was produced compared to the 884,575 tons in 2004/05 season. The report attributed the decline to drought effects experienced during the 2004/05 growing season. Hence droughts and floods can impact the economy of a country. These extreme events have given rise to the need for adaptation as a way of surviving the impacts caused by these extreme climatic conditions. Adaptation, in this study, is defined as adjustments to natural or human systems in response to experienced or future variability and extreme events or their effects. It is understood to be a function of the present or future vulnerabilities. Some of the adaptation measures to changes in climatic conditions include the promotion of early maturing/drought resistance crops, promotion of irrigation and efficient use of water resources, diversification to other activities less susceptible to impacts of extreme climate variability. The Zambian government has largely been promoting agro-ecological region specific maize varieties as an adaptive management tool to the impacts of climate change and variability (Lungu, 2006).

It is noteworthy that there are many other factors which affect maize growing other than rainfall and temperature (climatic factors), such as government policy, distribution of inputs, transportation of produce and availability of markets for the produce. However, this study was only conducted within the scope of effects of climatic factors on maize growing and so these other factors were outside the scope of the study. Hence, it assessed the climatic variations and adaptation measures in southern Zambia and the implications on maize growing. The rainfall variation was assessed over the period 1910 to 2009 while temperature variation was assessed over the period 1945 to 2009. The difference in periods was due to non-availability of temperature data for sampled stations as the earliest recorded temperature readings in the region was in 1945. However, both periods are long enough to accurately assess the climatic trends for southern Zambia. The study further assessed suitability of particular maize varieties in AER II based on their rainfall and temperature requirements, adaptability to the environment and to different climatic conditions and their potential yields.

1.2 Statement of the Problem

Zambia has experienced an increase in frequency and intensity of droughts and floods since the 1980s (GRZ, 2007; World Bank, 2006; Jain, 2007; Ngoma, 2008, Shitumbanuma, 2008) and this has given rise to the need for long-term adaptation measures for small scale farmers in AER II as well as coming up with effective coping strategies for these farmers. Furthermore, there is a need to understand the driving climatic factors and trends which have given rise to these climatic hazards.

These frequent climatic hazards have led to the government emphasizing on agro-ecological specific maize varieties as an adaptive management strategy. Hence, with the privatization process introduced in the 1990s, the government started promoting private companies involved in plant breeding as opposed to only supporting the parastatal company ZAMSEED which had until then been the only seed breeding company in the country. Since then, these seed companies have introduced several maize varieties on the market specifically suited to the climatic conditions in different agro-ecological regions. However, use of these varieties requires that the farmer has prior knowledge of the rainfall and temperature conditions in their area since these hybrid seeds are suited to a limited range of climates. Failure to meet the required climatic conditions can result in total loss of the yield as many of these hybrid seeds are not easily adaptable to the different environmental and climatic conditions. This means that a farmer has to know not only the expected weather conditions for his area but also the climatic conditions in which these seed varieties have optimum performance. Hence this complex use of these recommended maize varieties for different AERs has further led to confusion contributing to small-scale farmers' lack of understanding of the most suitable maize varieties for the climatic conditions existing in their area. This has been exacerbated by the farmers' lack of understanding of climatic requirements and adaptability of different maize varieties. Hence, farmers end up buying certified maize varieties that are cheap on the market but which may not necessarily be the best variety for that area.

This situation arose due to the limited agricultural extension services available to farmers in the region and increased commercialization of the seed breeding industry. There is also not only information lag between the climate data producer (Zambia Meteorological Department) and climate data users like small-scale farmers which makes it difficult for small-scale farmers to know the weather conditions for their area for a particular growing season but also a lack of efficient mechanism for accurate prediction of rainfall conditions in advance and disseminating the predicted information.

With this background, the study investigated climatic trends in AER II which have led to the emphasis on AER specific maize varieties. It also investigated the most suitable maize variety for cultivation in AER II based on adaptability to the local conditions, potential yields and climatic conditions of the area.

1.3 Aim

The aim of this study was to assess the climatic variations and adaptation measures by small-scale farmers in Zambia's AER II for the purpose of ensuring viability of arable agriculture.

1.4 Objectives

The study had the following objectives:

1. To examine climate variability in AER II usingthe means of decadal observed rainfall from 1910 to 2009 as well as decadal means of temperature from 1945 to 2009.
2. To assess the implications of climate variability on small-scale arable agriculture in AER II.
3. To determine adaptation measures and coping strategies by small-scale farmers in AER II to reduce the impacts of extreme climate variability.
4. To determine the recommended maize varieties for AER II based on adaptability to climatic conditions and potential yields.

1.5 Hypothesis

The hypothesis below was used to test objective one quantitatively:

1. There is no significant difference between the decadal means of rainfall from 1910 to 2009 as well as decadal mean temperatures from 1945 to 2009 in AERII.

1.6 Research Questions

Objectives 2 to 4 were tested qualitatively using the following research questions:

1. What are the implications of extreme climate events on small-scale arable agriculture in AER II?
2. What are the coping strategies employed by small-scale farmers in AER II to survive the impacts of climate variability?
3. What are the recommended maize varieties for AER II?

1.7 Rationale

Due to climatic variations, different studies have indicated crop yield reductions in Zambia. The World Food Programme (2006) reported that the prolonged droughts of 2004/05 reduced food harvest in many provinces of Zambia and that about 2.3 million people were estimated to need emergency food aid. In addition, SADC (2006) reported that cereal production in Zambia had been low due to dry spells and early stoppage of the rains. As a result, Zambia needed to import an extra 269, 000 tons of cereals compared to the previous year (i.e. 2005) when the country had recorded a surplus of 280,000 tons. Furthermore, over the last three decades, the frequency of extreme climate events such as high surface temperatures, floods and droughts have increased over the entire globe (IPCC, 2007). Zambia has experienced an increase in drought frequency and intensity in the last 20 years, notable ones being in 1991/92, 1994/95, 1997/98 (Muchinda, 2001). Therefore, there is a need for investigating the climatic variations with respect to maize production in AER II region. It is hoped that the study will clarify the confusion whereby all maize varieties are recommended for AERII despite the differences in moisture requirements. Hence the results of the study should help in improving the distribution of maize varieties to various regions and assist farmers to effectively adapt to climate variation. Most studies previously conducted in the Southern Province (Chifuwe, 2006) or Lusaka Province (Banda,

2005) or at national level (Sichingabula, 1998) concentrated on drought assessment. While other studies have been done to establish the evidence of occurrence of climate change (Shitumbanuma, 2008), none has been done specifically to assess the climatic variation in AER II. This study will add to the body of knowledge on the subject of variability in Zambia for future research.

1.8 Organization of the Thesis

Chapter One outlines the background of the study, the problem statement, objectives of the study, the hypothesis and research questions and the rationale of the study.

Chapter Two reviews the literature on climate variability and change and the development of seed breeding in Zambia. It also gives the state of climate variability and change in Africa and Zambia, the drought and flood occurrence in the country and also the climatic factors affecting maize growing.

Chapter Three outlines the study area in terms of location and the physical and socio-economic characteristics.

Chapter Four presents the methodology used in data collection of primary and secondary data and further outlines the analytical techniques used.

Chapter Five presents the results of the study based on appropriate statistical techniques used in form of graphs and tables.

Chapter Six Discusses and interprets the results of the study and highlight the implications of climate variability on small-scale farmers.

Chapter Seven summarizes the study and highlights conclusions on the climatic conditions of AER II for the study period and what the current state of the weather conditions implies for the farmers in this region. Finally, recommendations on adaptive alternatives drawn from the study are presented.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter outlines the theoretical framework of the research and reviews climate variability in Africa and Zambia. Climatic conditions of Zambia and the effects of temperature and rainfall on maize growing. Furthermore, the current status of seed breeding in Zambia will be highlighted.

2.2 Theoretical Framework- Principle of Uncertainty and Livelihood Diversification Analysis

The research was undertaken using the concepts of uncertainty and livelihood analysis and diversification. Uncertainty as relates to the future entails that the future becomes uncertain as one projects further into it i.e. the future is not perfectly known. This is because multiple factors are at play in shaping the future giving rise to increasing possibilities and divergence of trajectories with time. This is critical in considering risks and impacts attached to climate change because whilst it is widely acknowledged that climate change is a challenge of today (IPCC, 2007), it is equally recognized that the predictive capacity of climate science is relevant over time horizons of over 30 year periods. Below 30 years it is climate variability with limited ability to project the nature and extent of that variability. This ability further reduces with the increase in time periods above 30 years. These constraints on our ability to describe meaningful climate and development futures are critical in thinking about growth and development. Many of the development strategies and plans project a specific development trajectory, linked to a desired outcome (GRZ, 2010). This is appropriate where shorter time horizons, for example 5 years, are in use. However, for the longer time horizons, such as those relevant to the climate change debates, an approach built on multiple development pathways, with multiple development futures is more appropriate. This approach is rooted in development scenario planning, rather than planning for a particular development future.

Livelihood analysis involves the complexities of survival in poor communities while diversification recognizes that people do many different things, rather than just one for them to survive. Hence a farmer may also be involved in trade or fishing for him/her to survive. This is so because farming itself does not provide a sufficient means of survival in rural areas, hence people engage in a diverse portfolio of activities such as bee-keeping, craft making, casual labour, fishing, charcoal making and selling, etc. Therefore, livelihood diversification brings out survival strategies and techniques. Diversification is thought of as changing the nature of full-time occupation rather than enabling single individual or household to engage in multiple occupations (Ellis, 2000).

Extreme climatic events often lead small-scale farmers to engage in other activities as a mode of survival. The immediate short-term measures embarked on by these farmers such as trade, charcoal making and selling, wild fruit collection are referred to as the coping strategies while the long-term measures such as use of conservation farming techniques, use of early maturing/drought resistant crop varieties, water harvesting etc. are adaptation measures.

2.3 Understanding Climate Variability and Climate Change

Climate variability refers to weather variations from season to season (Ford, 1982). However, persistent change in climatic conditions over a long period of time (minimum of 30 years) to a point of shifting the long-term mean rainfall/temperature conditions could entail climate change. Climate Change, therefore, is any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2007). The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods minimum 30 years. Hence, Climate Change is any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2007). Clearly, these two definitions differ as to the cause of climate change. However, regardless of the definition of climate change adopted, this study looked at climate variability leading to change whether anthropogenically induced or otherwise.

2.4 Global Greenhouse Gas (GHG) Emissions

There are several important GHGs such as Carbon dioxide (CO_2), Methane and Nitrous oxides. However, CO_2 is the most important anthropogenic greenhouse gas. The global atmospheric concentration of carbon dioxide has increased from a pre-industrial value of about 280 ppm to about 396 ppm in 2012 (Mauna Loa, 2012). The atmospheric concentration of CO_2 in 2005 exceeded by far the natural range over the last 650,000 years (180 to 300 ppm) as determined from ice cores. The annual CO_2 concentration growth rate was larger during the last 10 years (1995–2005 average: 1.9 ppm per year), than it has been since the beginning of continuous direct atmospheric measurements (1960–2005 average: 1.4 ppm per year) although there is year-to-year variability in growth rates. The primary source of the increased atmospheric concentration of CO_2 since the pre-industrial period results from fossil fuel use. Annual fossil CO_2 emissions increased from an average of 6.4 GtC in the 1990s to 7.2 GtC in 2000–2005. CO_2 emissions associated with land-use change were estimated to be 1.6 GtC per year over the 1990s, although these estimates have a large uncertainty (IPCC, 2007).

2.5 Climate Variability and Change in Africa

A lot of work has been done on the rainfall variability in Africa (Nicholson and Entekhabi, 1987, Ogallo, 1984, Sichingabula, 1998). However, most of these works do not represent a period long enough to describe climate change satisfactorily (Banda, 2005), although their results do indicate the general trend of climate change on the continent. A comprehensive study of climate change should be done on results covering a long period (minimum 30 years) and should include both rainfall and temperature variability in the long-run. A study by Nicholson and Entekhabi (1987), conducted on annual rainfall series in Africa revealed positive trends anomalies. Such results showed that most of the annual series generally had an oscillatory characteristic without significant trends. This gives the impression that rainfall in Africa is oscillatory in time.

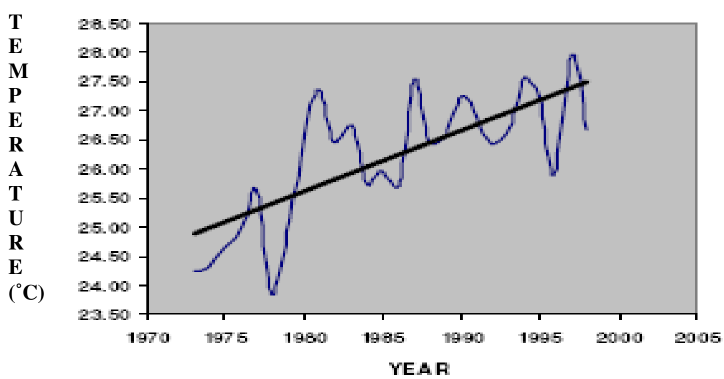
Nicholson and Entekhabi (1987) noted the similarity in the series for the sub-Saharan region which had above normal rainfall in 1930-1940 and 1950-1960 and below normal rainfall in 1910-1920, 1940-1950 and 1968-1984. Normal rainfall in this study was taken as the mean rainfall from 1910 to 1984 which was the period of study. This negative trend observed after 1968 depicted severe drought conditions which prevailed in the Sahel in those years. The study also established oscillatory behaviour was also observed in the Northern, Southern Kalahari and East African countries. Nicholson and Entekhabi (1987) studied Sea Surface Temperatures (SST's) along the South West coast of Africa in relation to rainfall variability in the equatorial and Southern Africa and showed evidence that variability of SST's in the upwelling regions were most pronounced every 2-2.5, 3.3-3.8 and 5-6 years giving further support to the oscillatory behaviour. The study also showed strong relationships with rainfall throughout equatorial and Southern Africa. It had been empirically established that anthropogenic emissions of greenhouse gases and other atmospheric pollutants were changing global and regional climates. Global surface temperature has increased by over 0.8°C in the past 100 years (The World Bank, 2010). Jain (2007) also reported a rate of warming of about 0.5°C per decade for Southern Africa during the present century.

2.6 Climatic Conditions in Zambia

Zambia is located entirely within the tropical savanna zone, meaning that the country experiences a tropical climate. An analysis of Zambia's temperature and rainfall conditions is described and their trends shown below.

2.6.1 Temperature

Shitumbanuma (2008) reported that Zambian temperatures are increasing at the rate of 0.32 degrees Celsius per decade. In fact, after computing the mean seasonal (November to April) temperatures for the year's 1970 to 2005 using information from 32 Meteorological stations in Zambia, the results gave an upward trend (World Bank, 2006) as shown in Figure 1:



Source: World Bank (2006)

Figure 1: Mean Seasonal Temperature Trends in Zambia, 1970-2005

2.6.2 Rainfall

Zambia's rainfall events run from October to March with occasional rains in April and sometimes even in May (Kurji *et al*, 2003). On average the country receives about 1000 mm of rainfall per year with variations of about 1400 mm in the North and 600 mm in the South (GRZ, 2002). According to Kurji *et al* (2003) the average amount of rain received in some parts of southern province is often below what the farmers require. GRZ (2002) said that Zambia's climatic conditions have changed in that since early 1980s, the rainy season has been starting late and the rains have been withdrawing early, and that temperature has been observed to have increased by one degree since the 1970s. The World Bank (2006) also reported that Zambia has been experiencing an increase in floods, temperature and drought frequency and intensity, which many scientists have attributed to long term climate change.

2.7 Climate Variability and Climate Change in Zambia

Jain (2007) analyzed temperature readings from 32 meteorological stations in Zambia over a period of 30 years. The results indicated that the summer temperature in Zambia have been steadily increasing especially over the past 3 decades. The rate of increase is highest in November–December as compared to other periods across all agro-ecological zones. Hutchinson (1974) humanized the effects when he observed that although mean values of rainfall are indicative of the general rainfall regime, variation from the mean have just as important an effect on man's response to climate; for example, the dry 1972/73 season reduced the maize crop by up to 50% in some areas.

2.8 Climatic Factors Affecting Maize Growing

Maize production in Zambia is affected by among other factors droughts, dry spells and floods. For example, World Bank (2006) reported that due to repeated droughts maize production had shown a general decline from early 1990's onwards in Zambia. Flooding of lowland areas and death of animals (used as draught power) in many places also affected the output (FAO, 1998).

2.8.1 Rainfall

Drought affects agricultural production on about 60% of the land areas in the tropics (Sanchez *et al,* 1977). It reduces maize yields by about 15% annually in the lowland tropics and subtropics amounting to an estimated loss of 16 million tons of grain (Lafitte, 2000; Edmeades *et al*., 1992). Maize needs at least 500mm of well –distributed rainfall during the season. The impacts of droughts on crops depend on the duration of the drought and the time of occurrence. Prolonged droughts occurring during crop establishment can be very devastating as seedlings die and the plant population is reduced. Furthermore, if droughts occur during flowering, it has an amplified effect on the yield as it severely restricts formation of grains per plant due to impaired pollination or because fertilized ovules stop growing (Edmeades *et al.*, 1992). Historical accounts, therefore, shows that, if droughts occurred in December, January, February and March (characterizing protracted droughts) (Colonial Office, 1930) worse crop yields occur since crops have no chance of growing and maturing. The case is different if the drought occurred in a different time sequence.

2.8.2 Temperature

Stewart *et al* (1997) indicated that during vegetative growth, maize has a maximum response to temperature of between 25 - 30°C and during reproductive growth, maize responds well to temperatures above 12°C. With increased temperature, CO_2 assimilation rate undergoes thermal acclimation (Dawyer, *et al*, 2006). High temperature also affects the plant through its effects on the availability of water which is very important in the process of photosynthesis. Thus, with high temperature and strong solar radiation, evapo-transpiration increases (Holmen, 2003), thereby increasing water stress on the plant which reduces maximal photosynthesis, CO_2 quantum yield, and photosynthetically photon flux density (PPFD). Furthermore, maize being a C_4 plant is also affected by low temperatures in that it reduces its growth rate (Sage and Kubien, 2007).

2.9 Drought Occurrence in Zambia

Sichingabula (1998) contended that droughts in Zambia occurred every year as there was always a part of the country experiencing below normal rainfall. The probability of drought occurrence was lowest in the wettest northeastern area (34%) and highest in the driest southwestern area (66%). For most of the country it was found to be 50%. The droughts of 1924, 1933, 1946, 1949 and 1965 impacted more than 80% of the 46 districts studied. The 1949 event was the most wide spread and impacted the greatest area (92%). The 1987 and 1992 drought each impacted 90% and 88% of the country's area, respectively (Sichingabula, 1998). Table 1 shows the country-wide drought occurrences between 1976 and 2002.

Table 1: Country-wide Drought Occurrences; 1976-2002

Period	Drought Years	Frequency over total time
1976-1988	1979,1981,1983, 1987	4 droughts in 12 years
1989-2002	1990,1991,1992,1994,1995,1996,1997,1998, 1999	9 droughts in 13 years

Source: Banda (2005)

The rate of drought occurrence in Zambia has been increasing over the past decades. Fewer droughts were recorded in Zambia between 1976 and 1988 but between 1989 and 2002 there was an increase in drought frequency (Table 1).

If the historical record (1921-1996) is to go by, droughts covering more than three quarters of the country could be expected at least once in a decade. This usually happens when the centers of drought are located in high rainfall areas and the impact is more than 80% of the country's area. The study conducted by Tiffen and Mulele (1994) revealed that rainfall in Zambia was unimodal due to the southern movement of the Inter-Tropical Convergence Zone (ITCZ) and this caused the southern half of Zambia to be the worst affected by the 1991-92 drought. Generally, the main areas affected by the 1991-92 and 1995/96 droughts were the low and medium rainfall zones, which include some of the more highly populated rural areas of Zambia and the provinces which normally produce a surplus of Maize for sale to urban areas (Chifuwe, 2006). These droughts proved to be very devastating to Zambia and the country had to depend on the international community to provide food and aid towards drought relief amounting to 970,000 metric tons (for the 1991/92 drought) and 81,274 metric tons (for the 1995/96 drought) of relief grain (maize, wheat, sorghum, and rice). Apart from being devastating, droughts can also be very expensive as was seen in the 1991/92 drought which was valued at US$70 million and during that season, Zambia could only manage to harvest 4.5million bags instead of 12 million bags (PAM, 1993; 95; Banda et al., 1997) hence the need to spend in order to offset the deficit.

According to Chipeta (1998), Zambia experienced several droughts with those occurring between 1921 and 1930 being more severe. He further stated that 1930-1950 was alternated by rapidly wet years, but on the whole, the rainfall season was relatively good. From 1981 to 1992 wet years were rare and drought was normal for most of the years. In 1981-82 droughts intensified and in 1991-92, Zambia experienced what Chipeta (1998) described as one of the worst droughts during the century and he attributed the cause of this drought to weakness in rainfall producing mechanisms and the El Niño effect. The El Niño effect is the warming of the Sea Surface Temperatures (SST's) in the Pacific Ocean at certain years causing wet and dry conditions on some parts of the globe. It should however, be noted that not all El Niño are associated with droughts in Zambia (Kamuna, 2005). The 1997-98 El Niño had two effects on the weather of Zambia that is; excessive rain in the northern half and normal to below normal rainfall in the southern half.

2.10 Flood Occurrence in Zambia

The effects of flooding cuts across all sectors of the economy and these effects include starvation due to crop loss, reduction of cultivatable land and soil erosion, relocations due to shelter loss, destruction of communication and destruction of infrastructure among other effects. Hence, floods like droughts severely affect the economic prosperity of not only the affected households but also the country. DMMU (2007) (in GRZ, 2007) reported that the 2007 floods affected 41 out of 72 districts in Zambia which included areas never before affected by flooding. Historical data proves that recent floods have been more widespread and more frequent and in some years too early in areas where they are expected late (e.g. Western Province) and hence caught even people with traditional coping mechanisms unprepared. These effects could likely be indicators of the changing pattern of climate in Zambia. Between the years 2002 and 2007, Zambia experienced two major floods (2002/3 and 2006/7) (GRZ, 2007). The country further experienced massive flooding in the years 2008/9 and 2009/10. Floods are more destructive if they occur in dry areas as compared to wet areas. This is so because dry areas have reduced vegetative cover and floods tend to sweep the top fertile soil layers together with the little vegetative cover available causing severe soil degradation. On the other hand, wet areas have extensive vegetative cover which usually prevents the destructive traits of floods. If floods occur in a maize field, they are likely to have a more destructive effect as compared to crops like sorghum, millet and okra which are rarely affected by impacts of floods. Hence these crops can be used as coping strategy to impacts of floods.

2.11 Agro-Ecological Regions (AERs) in Zambia

Zambia is divided into three agro-ecological regions (AERs) based on the amount of annual rainfall, relief and growing period. The regions are shown in Figure 2 and described below:

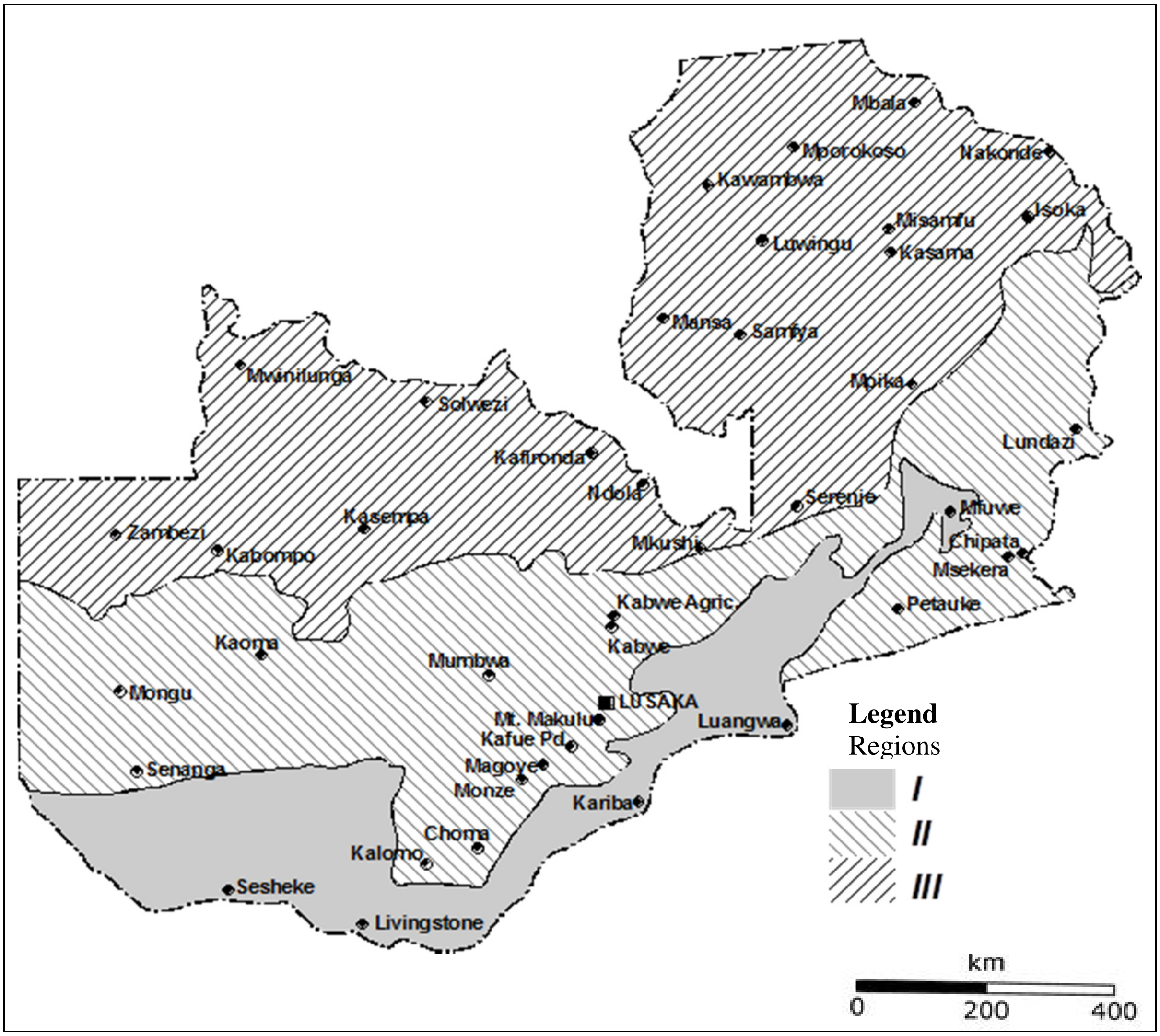


Figure 2: Agro-Ecological Regions of Zambia

Region I: This lies in western and southern Zambia and Eastern river valleys and it receives less than 800mm of rainfall annually. It accounts for 15% of the total land area of the country. This region used to be the food basket of the nation but for the last twenty (20) years (World Bank, 2006), but currently, it is not because of the poor distribution and amount of rainfall received (Ngoma, 2008). Other features include: short growing season (80-120days) (GRZ, 2002), high temperatures during the growing season, and high risk of drought, flat and deep topography, contains mostly of Haptic Luvisols, contains Haptic solonetz on the flat lands and Dystric Leptosols on the hills and ridges. Soils are loamy and clay, reddish course sandy, poorly drained sandy, and shallow and gravel in rolling to hilly areas (Saasa, 2003; Ngoma, 2008).

Region II: This region formed the study area (Chapter 3). The characteristics of AER II are explained in section 3.2.

Region III: This comprises part of Central African plateau covering Northern, Luapula, Copper belt, North Western provinces and Northern parts of Serenje and Mkushi Districts (Saasa, 2003). It constitutes the northern part of the country and receives over 1000mm of rainfall annually (World Bank, 2006) with other features as long growing season (up to 190 days), low probability of drought, and cooler temperatures during the growing season. This region is suitable for late maturing maize varieties (GRZ, 2002; World Bank, 2006). Soils in the region are mostly Harpic Acrisols and the most practiced traditional farming systems by farmers in this region are mainly based on slash and burn and shifting cultivation. Soils in the region are red to brown clayey loamy; shallow and gravel in rolling hilly areas; clay, red in colour, poorly to very poorly drained flood plain (Brammer 1973) and course sandy in pan *dambos* (wetlands) on Kalahari sand (Saasa, 2003). Main crops grown include cassava, maize, sunflower, coffee, tea and many others (Ngoma, 2008).

Variability both within and among the regions occur in terms of climate and soils and this makes it possible for some areas to be more suitable for some crops than others. Such variability is responsible for the varieties in crops grown throughout the country.

2.12 Maize Seed Breeding and Agricultural Research in Zambia

Agriculture is the mainstay for the majority of people in Zambia. It has been an increasingly important sector in the Zambian economy since the mineral sector, which was the backbone of the economy from post-independence times (1964) until the late 1980s, declined. The agriculture sector generates about 18% to 20% of the country's GDP (Jain, 2007). Small-scale farmers represent 79% of the farming community and these largely depend on maize growing for their survival (GRZ, 2002b). The Eastern Province is the largest annual producer of maize in Zambia followed by the Southern and Central Provinces. The rest of the provinces only produce small amounts of maize. Unit yield of maize production stands at 1.5-2.0t/ha each year in most of the provinces but for Western Province where it often does not reach 1.0t/ha each year (JAICAF, 2008).The 1990 agricultural census indicated that 379,784 farming households in Zambia – 73% of the total – plant maize, 97% of which are small-scale farmers with 1-9 ha of land. Small-scale farmers accounted for 69% of the maize planting area and 61% of total production. On average, 52% of the small-scale farmers plant maize on less than 1ha of land and tend to use recycled seed. This outlines the contribution of the agriculture sector to the Zambian economy, hence the support it receives from the government through research in improved AER specific hybrid maize varieties.

Lungu (2006) argued that a vibrant seed industry is the key to agricultural progress. A farmer requires regular supplies of good quality seed of improved varieties to satisfy both his and consumer demands. Hence, the need for improved breeding and production of hybrid seed to suit the different agro-ecological areas and the seed industry has been undergoing experimentation and research. Agricultural experiment and research in Zambia dates back to 1922, during the colonial period. The activities initially focused on cash crops grown by European settlers including maize, cotton and tobacco. Comprehensive experiment and research started in 1953, when the predecessor of the present Zambia Agricultural Research Institute (ZARI) was established (JAICAF, 2008). The Structural Adjustment Program (SAP) implemented in the 1990s explored the possibility of involving the private sector in experiment and research projects which were then run by the government. This effort led to the creation of a new research organization as agricultural research trust, in addition to the existing national agricultural research institute. Some of the plant breeding experiments and research activities, including improvement in crop varieties, are now conducted by private companies and seed providers while some research activities are conducted by government agencies such as the Ministry of Agriculture and Cooperatives (MACO), the National Institute for Scientific and Industrial Research Institute (NISIR) under the Ministry of Science, Technology and Vocational Training. Furthermore, the School of Agricultural Sciences at the University of Zambia (UNZA) also conducts its own research activities.

The seed industry covers a broad range of activities such as plant breeding or crop improvement, seed production and certification. Plant breeding is a vital component of a successful seed industry (Lungu, 2006). A strong seed industry depends on an equally strong Plant Breeding Programme that will churn out improved crop varieties on a continuing basis. Currently, four main entities are involved in agricultural experiment and research activities in Zambia, namely;

- the Agricultural Research Institute of the Ministry of Agriculture and Cooperatives,
- National Institute for Scientific and Industrial Research Institute (NISIR),
- UNZA School of Agricultural Sciences and
- the private sector companies such as ZAMSEED, SEEDCO, MRI Seed and PANNAR

The main objectives for maize breeding include the development of varieties resistant to non-biological stresses such as aridity, low nitrogen and low pH, as well as to biological stresses including grey leaf spot, leaf blight and stored products pests (JAICAF, 2008). Hybrids are categorized into early-, medium- and late-maturing, based on the timing of breeding. These hybrids are given number series of 400, 600 and 700, respectively. They are also classified according to adaptability to the three agro-ecological regions in Zambia.

2.12.1 The Zambia Seed Company Ltd (ZAMSEED)

ZAMSEED is a private company in which GRZ had 10% shares which has since been disposed of and sold to Zambians. It was the first private seed company in Zambia and hence enjoyed a lot of good will from the government and this propelled the company's growth in research and development. The company was the sole recipient of seed varieties bred from the Soils and Crops Research Branch (SCRB) of the Ministry of Agriculture and Co-operatives (MACO). ZAMSEED with the help of SCRB produced the very first hybrid in Zambia, Mount Makulu 752 i.e. MM 752 in 1983. There was a memorandum of understanding between the SCRB and the Zambia Seed Company (ZAMSEED) whereby all publicly bred crop varieties automatically became the property of the then only seed company in Zambia, ZAMSEED. In turn ZAMSEED was supposed to assist Government efforts in funding plant breeding research by the SCRB. With the policy of liberalization which saw an opening up to other seed companies in the country, that arrangement of ZASEED automatically owning all the publicly bred varieties came to an end in 1998. Any seed company could now bid for rights to multiply and market these varieties. However, despite these policy changes the SCRB still remains the dominant plant breeding institution in the country and continues to release new varieties of varying crops although, at the moment, there is no clear policy on who the beneficiaries of these publicly bred varieties is (Lungu, 2006). Hence all the plant breeding work was being done by the research branch of MACO until 2006 when ZAMSEED produced their first seed varieties (ZMS varieties) although the company formed its own Research and Development (R&D) department four years before their first variety was produced. Under the government-sponsored Fertilizer Support Programme (FSP), ZAMSEED now markets 17 maize hybrids and 5 open pollinated varieties, and enjoys a 30-50% market share. Hybrids account for some 75% of its sales.

2.12.2 SEEDCO Company LTD

SEEDCO is a private Zimbabwean Seed Company operating in Zambia since 1995, mainly as a marketing outlet for the mother company in Zimbabwe. SEEDCO Zambia has only been engaged in line evaluation for the purpose of generating data on the adaptation of their varieties to the Zambia growing conditions. This information has enabled the company to release their varieties in Zambia. All the plant breeding work for SEEDCO is done in Zimbabwe with only a few members of staff manning the line evaluation form of plant breeding and seed multiplication work in Zambia (Lungu, 2006). The entire research budget for SEEDCO is devoted to plant breeding with maize receiving 90 % of all research resources. The company conducts a number of field evaluation trials in Zambia and handles 128 experimental plots of maize. Since the company started operating in Zambia, in 1995 SEEDCO released 2 wheat varieties, 14 maize varieties and 6 soybean varieties. Currently, the company has been promoting 16 maize varieties for the 2010/2011 growing season including the SC 727 which is a new hybrid yet to hit the market with potential yield of 17-18 ton/ha.

2.12.3 PANNAR Seed Company LTD

PANNAR Seed Co is a private South African Seed Company and hence most of their plant breeders are based in South Africa. The company had been operating in Zambia for about 13 years but has not done much in terms of plant breeding research. Instead, their concentration has been on evaluation of the lines and experimental hybrids for performance in Zambia. This was so as to generate variety performance data which is needed for official variety release in Zambia. The PANNAR office in Zambia has been used simply as a trading outpost for this South African Seed Company in Zambia. The crops being evaluated are wheat, maize and soybeans. Maize receives 95% of the research budget and the other two crops receiving only a small proportion of 2.5% each. The company released 4 varieties of maize in in 1995 and 4 varieties of maize in

2000, 4 varieties in 2006, among others. Hence it has been promoting a total of 19 maize varieties since its inception in Zambia.

2.12.4 Maize Research Institute Seed (MRI SEED) Company

This is also a private company which is an offshoot of the MRI of the then Yugoslavia. This Yugoslav company bought a farm in Zambia in 1980 and used it as a winter nursery site for advancing maize generations from its breeding programme in Europe. These too formed a memorandum of understanding with the SCRB of MACO in the area of germplasm exchange and training of Zambian maize breeders. The MRI has devoted over 80% of its total research budget to plant breeding. Currently, the company is promoting 16 maize hybrid varieties. . The company had a 30-32% market share within the governmental Fertilizer Support Programme (FSP).

2.13 Recommended Maize Varieties in the Different AERs in Zambia

Maize does well under frost free conditions and when mean daily temperatures are above 15˚C. For germination, the lowest mean daily temperature is about 10˚C with 18˚C to 20˚C being optimum (GRZ 2002). Hot sunny weather with short rainy intervals is favourable to maize growth. Maize varieties suited and recommended for the different AERs of Zambia have been developed (Appendix 1). However, all varieties had been recommended for AER II despite the differences in days to maturity and moisture and temperature requirements. Hence, farmers in drought prone areas i.e. AER I and II were advised to plant maize varieties with high yield potential, and which have been found to have high water use efficiencies and has less days to maturity though they also have a lower potential yield. The potential yield for the very early maturing varieties was between 2 to 3 t/ha with a 110 days to maturity. The medium maturing varieties had between 120 to 130 days to maturity while the late maturing varieties required more than 135 to mature (Table 2).

Table 2: Maturity Classes for the different Maize Varieties

Maturity Group	Days to Maturity	Average Potential Yield (t/ha)
Very Early Maturing	Below 110 days	2.0-3.0
Early Maturing	110-120 days	3.0-6.5
Medium Maturing	120-135 days	5.5-9.0
Late Maturing	Above 135 days	6.5-15.0

Source: ZASTA (2008)

Small-scale farmers in AER II which has a crop growing period of about 140days are encouraged to plant the early maturing and medium maturing maize varieties. These varieties have lower potential yields as compared to the late maturing varieties but they are adaptable to the medium rainfall conditions of this region.

2.14 Conservation Agriculture - A Sustainable Adaptation Measure

Conservation Agriculture (CA) is currently perceived a very important sustainable option for farmers if they are to cope with the adverse impacts of droughts and floods. As its name suggests, it conserves not only the soil organic matter and hence soil fertility, but it also conserves soil moisture making it an important adaptation measure to climate variability. It involves a series of sound land husbandry practices which minimize soil disturbance, retain crop residues and use crop rotations to reduce impacts of pests and diseases (Morgan, 2009), hence the system is based on the principles of minimum mechanical soil disturbance; permanent organic soil cover with crop residues or cover crops; and diversified crop rotations (Umar et al, 2011; Thierfelder and Wall, 2009). CA promotes minimum tillage of the land by the use of basin farming, ripping or pot holing in which seeds are planted in these basins, rip lines or pot holes made without necessarily inverting or disturbing all the soil surface, which otherwise leaves it susceptible to agents of erosion and accelerates oxidation of soil organic matter.

Under CA leguminous plants are planted with the cultivated cereal crops either together or sequentially as these fix atmospheric nitrogen into the soil and make it available to the cereal crops. The most important legume tree in this family is *Faidherbia albida,* also commonly known as the Winter Thorn or locally as *Musangu*. This is so because a mature forest of *F. albida* can provide the equivalent of 70 kgs of nitrogen per hectare per annum which can be used by annual crops growing under the tree (Morgan, 2009). The tree does not compete with crops for sunlight as it sheds its leaves during the rainy season and allows light to penetrate to the growing crops underneath. Furthermore, *Musangu* tree does not compete with crops for water due to its deep rooting habit but ends up bringing important nutrients from deeper layers of the soil, where crop roots cannot reach. These nutrients can then be used by crops. Hence the most important characteristics of Musangu is its reverse phenology, the fact that it does not shade crops which grows under it. Besides this, the nitrogen fixation and addition of nutrients from its leaf and pod litter and its long tap roots, the provision of fodder during dry season when livestock is in serious need of such fodder, makes it special. Furthermore, the tree is indigenous and occurs in dry areas where CA is also recently being promoted. Figure 17 shows a full-grown *Musangu* tree.

The CA promoted in Zambia involves several key practices such as dry-season land preparation using minimum tillage systems, crop residue retention, precise input application as seeds and fertilizers are placed directly into basins or ripped furrows and nitrogen-fixing rotations (Umar et.al, 2011). Conservation Farming Unit (CFU) of the Zambia National Farmers Union (ZNFU) has been developing and promoting CA for the past decade. The Zambian government, through its agriculture extension services under the Ministry of Agriculture and Cooperatives (MACO) has also helped to train many small scale farmers to take up CA as a way of combating climate change. Umar et al (2011) reports that although data on the overall adaptation of CA in Zambia is fragmentary, available evidence suggests that between 20,000 and 60,000 Zambian farmers practiced some form of hand hoe CA during the 2001/2002 farming season while an additional 4,000 used rippers (Haggblade and Tembo, 2003). By 2006, the figure had risen to between 125,000 and 175,000 (CFU, 2006). As of 2003, a 10% rate of adoption among Zambian smallholders was reported (Baudron et. al, 2005). On the other hand, of the 300 larger commercial farmers in Zambia as of 2009, only less than 10 have fully changed to CA (Morgan, 2009)

Promotion of CA in Zambia has been done by a number of stakeholders. Ranging from the private sector, the government and the donor community. Umar et al (2011) reports that CFU under the ZNFU has been the chief promoter of CA while other promoters include Institute Agricultural and Engineering, Golden Valley Agricultural Research Trust (GART), Dunavant, Cooperative League of the USA (CLUSA), Land Management and Conservation Farming (LM&CF) and MACO. The funding for CA projects has mainly been provided by donors of and the Royal Norwegian government has been biggest donor since the inception of the Conservation Agriculture Program (CAP).

Benefits of CA have been evident as practitioners of CA have better coped with the impacts of climate change as they have been consistent with their yields compared to those with conventional means of agriculture. This is because, CA reduces soil erosion, reduce production costs and improve soil fertility (Morgan, 2009). A piece of land which has been consistently cultivated using CA for at least 5 years should see a reduction in the amount of mineral fertilizer required for crop growth. Even without applying fertilizer or while applying fertilizer that was very much below recommended rates, CA farmers have been able to enjoy good harvests (Umar et al 2011).

If CA is such a wonderful method of agriculture, why are there still only a few farmers practicing it? According to *conservationagricilture.net* the answer is a combination of ignorance and reluctance to make change. Use of leguminous trees like *F. albida* requires a long-term investment in the land to which most small scale farmers do not even have title deeds. This makes them reluctant to invest on such land. Furthermore, farmers interviewed in Monze, Sinazongwe, Katete, Chipata, Petauke and Mumbwa said that the digging of CA basins was more labour intensive than conventional agriculture using a traditional hand hoe (Umar et.al.) . While ripping is less labour demanding than both ploughing and basin making, very few farmers have access to rippers. Farmers with bigger pieces of land often fail to practice CA due to the labour involved. Hence, those who do, only practice on a small part. Indeed, a lot still needs to be done if CA is to be adopted by many small-scale farmers as a mode of agriculture.

CHAPTER THREE

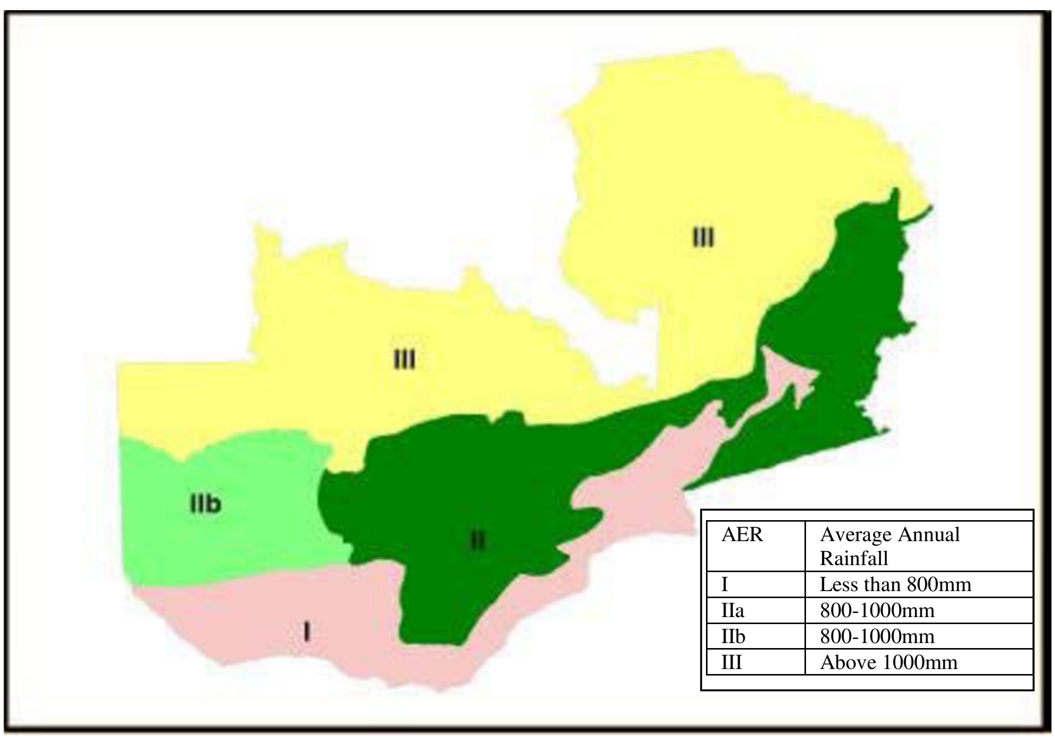
DESCRIPTION OF THE STUDY AREA

3.1 Introduction

This chapter describes physical and socio-economic characteristics of the study area at three different levels; Study area (AER II), Study town (Choma) and Study sites (Mbabala and Singani). Firstly, it highlights the major characteristics of AER II in which the study area falls, then describes the study town Choma in terms of the location, physical characteristics such as climate, soils, drainage and vegetation, and the socio-economic characteristics of the town. Finally, the chapter describes the study sites within Choma-Mbabala and Singani.

3.2 Agro-Ecological Region II

AER II is located in the central part of Zambia stretching from Mongu in the Western Province to Lundazi in the Eastern Province. The region consists of 27 towns which are covered either in full or in part (Figures 2 and 3).



AER	Average Annual Rainfall
I	Less than 800mm
IIa	800-1000mm
IIb	800-1000mm
III	Above 1000mm

Source: World Bank, 2006

Figure 3: The AERs of Zambia showing the divisions in AER II

AER II covers the sandveld plateau zone of the Central, Eastern, Lusaka and Southern Provinces. The area has a growing season of 120 to 150 days and receives about 800 to 1000mm of rainfall annually (GRZ,2002; World Bank, 2006; Jain, 2007). It is the most productive region of the country. The region has a total area of 27.4 million hectares of which 87% (23.8 million hectares) could be used for agricultural purposes, but only 50% is actually accessible. The rest has been set aside for national parks, game management areas and forests (GRZ, 2007). Despite this, it has the highest agricultural potential due to its fertile soils and is the most populous region in Zambia. This region forms the study area for this study. AER II is divided into two;

AER II a: Constitutes the Central sandveld plateaux of Central, Eastern, Lusaka and Southern Provinces and have the following characteristics:

- Contains soils of mainly Haplic Lixisols (FAO, 1973), Haplic Luvisols, Haplic Acrisols and other types.
- Support agriculture of different crops such sorghum, maize, Ground nuts cow peas, and many others (Ngoma, 2008). Hence the highest maize producing towns in Zambia are found in AER IIa (JAICAF, 2008).
- Higher rainfall with a longer crop growing period as compared to AER IIb

AER II b: Constitutes the Western plateau covering the semi-arid areas of Kalahari sand plateau and Zambezi Flood plains of Western province and has the following characteristics:

- Contains Ferrallic Aresols which are infertile (Ngoma, 2008)
- Contains course sands
- Support some Agriculture of some maize and sorghum on the uplands
- In the flood plain, rice, maize and sorghum are grown

3.3 Choma Town and the Study Sites Mbabala and Singani

3.3.1 Location

Choma District in the Southern Province of Zambia which was the study town is located within the latitudes 16°50’S to 16º83’S and between (www.timegenie.com) longitudes 26º30’ to 27°30’ E (Choma Municipal Council, 2006). The district covers an area of 7, 296 km^2 (CMC, 2006) and shares boundaries with five (5) districts, namely; Namwala to the north, Monze to the northwest, Gwembe to the west, Kalomo to the south and Sinazongwe to the southeast. All the five districts are accessible from Choma owing to the existence of a railway line and a major road network as a means of communication (Figure 4). Choma District has five (5) traditional chiefs, namely; Singani, Mapanza, Macha, Hamaundu and Moyo. Singani and Mbabala which formed the study sites are located about 15km south and 30km north of Choma town, respectively. Singani is along the Choma-Masuku Road while Mbabala is along the Choma-Namwala Road (Figures 4 and 5). The CSO (2010) divided the five chiefdoms of Choma into three constituencies-Choma, Mbabala and Pemba. Each of these chiefdoms is further divided into wards which in some instances cover villages (Figure 6).

3.3.2 Demographic Characteristics

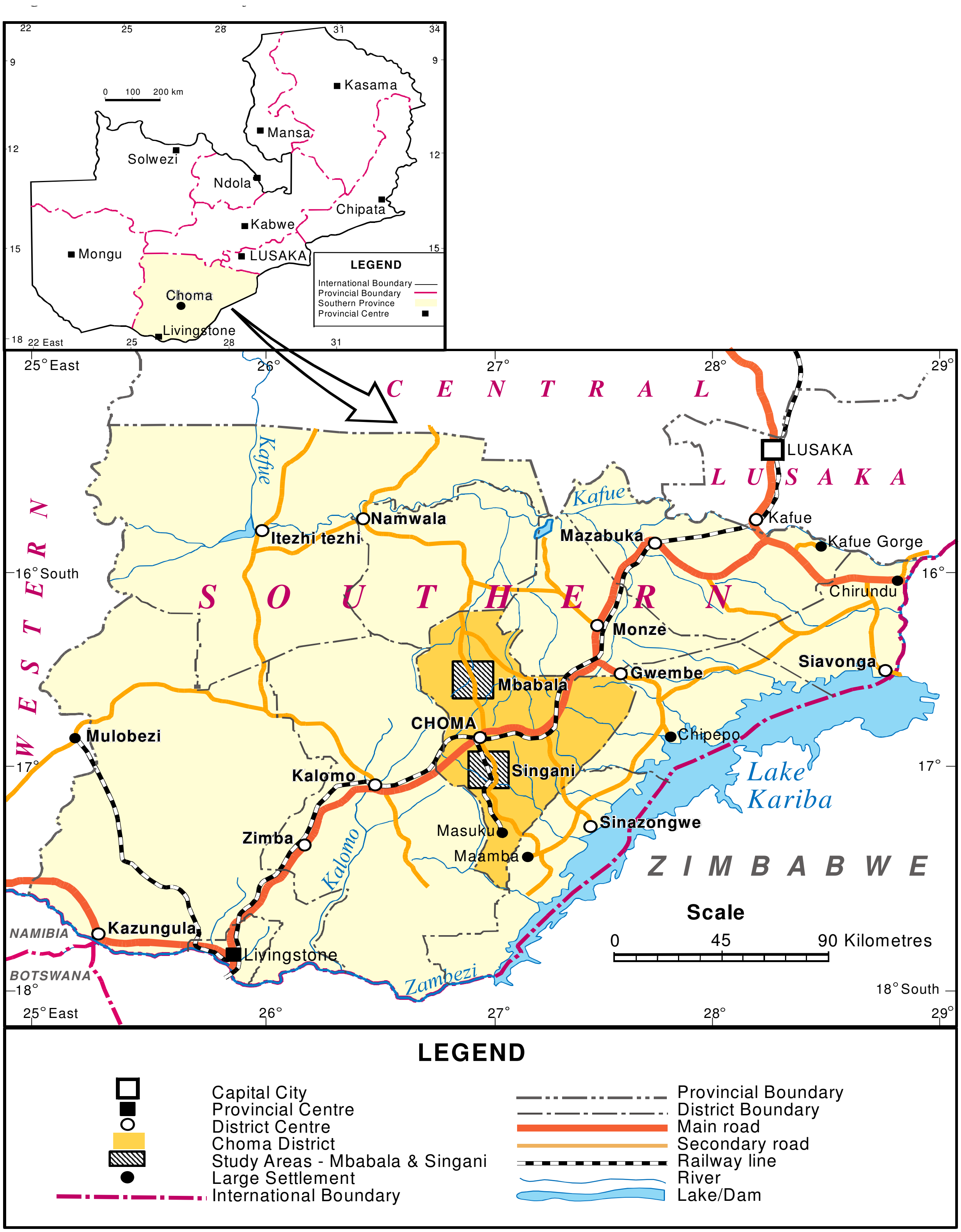
Choma District houses 27 wards split into 3 constituencies (Table 3). The two study sites Mbabala and Singani are among the 27 wards. Singani is home to about 1,585 households which houses a total population of 8,101 which is almost evenly gender split with 4,030 males and 4071 females. Mbabala on the other hand had about 2,490 households with a population of 13,966 (7,175 females and 6,791 males). The study town-Choma- is home to 45,733 households with 244,180 people (118, 486 males; 125,694 females (CSO, 2010)).

3.4 Physical Characteristics

3.4.1 Climate

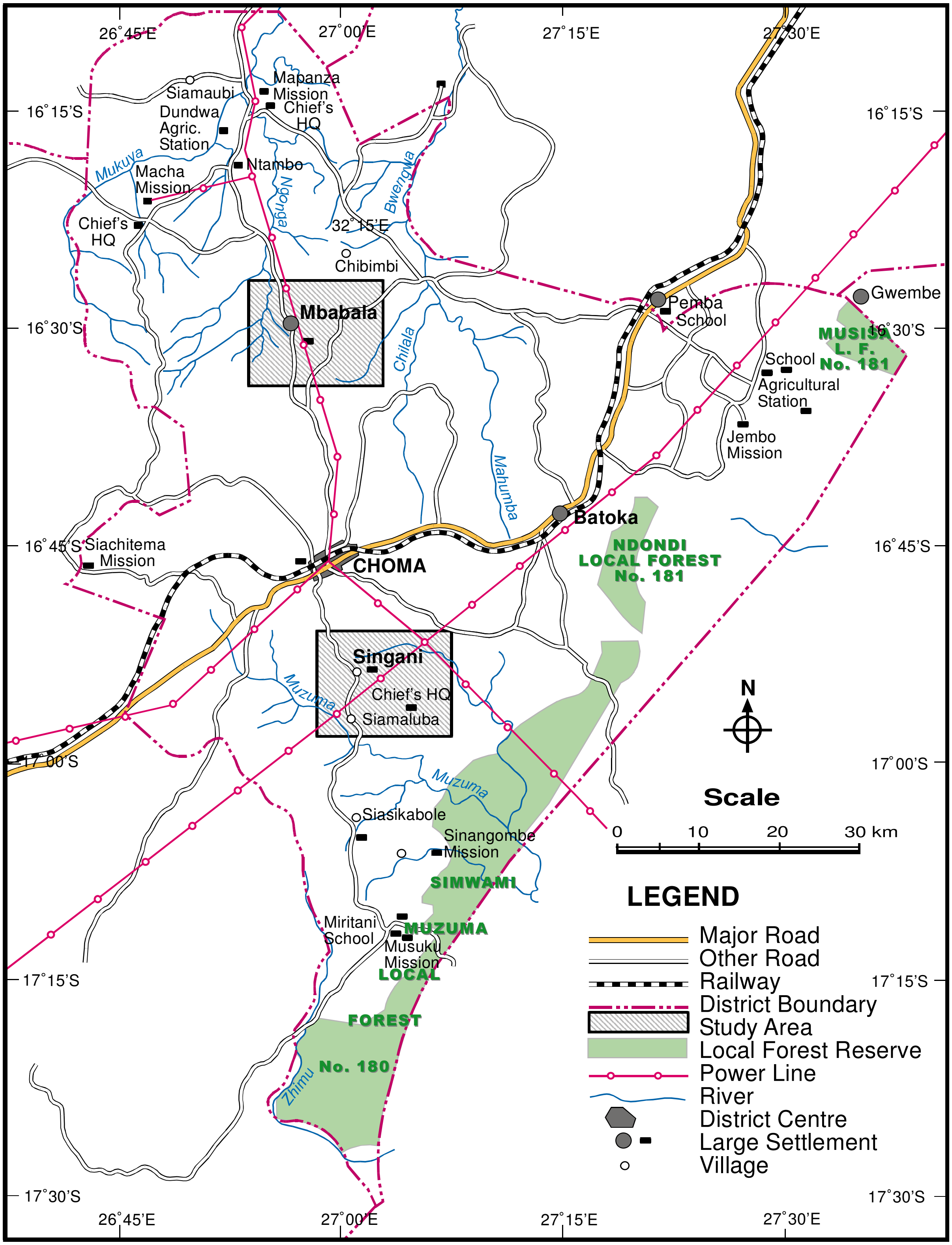
Generally, AER II, like most parts of Zambia, experiences tropical conditions that are moderated by altitude and rainy season that runs from October to April. The climatic conditions in the area are influenced by three (3) factors (GRZ, 2002a) :

- Inter-tropical Convergence Zone (ITCZ); which results in Northern part of the country receiving more rainfall than the Southern part.
- Altitude; that causes low temperatures in the plateau areas
- EL Nino; which has been associated with particular droughts in Zambia. The 1992 was largely as a result of the El Nino in the Pacific Ocean.



Source: Surveyor-General, 1973

Figure 4: Location of Choma District, Southern Province, Zambia



Source: Surveyor-General (SD-35-2 Choma, 1:250,000) 1973.

Figure 4: Location of Study Sites Singani and Mbabala in Choma District

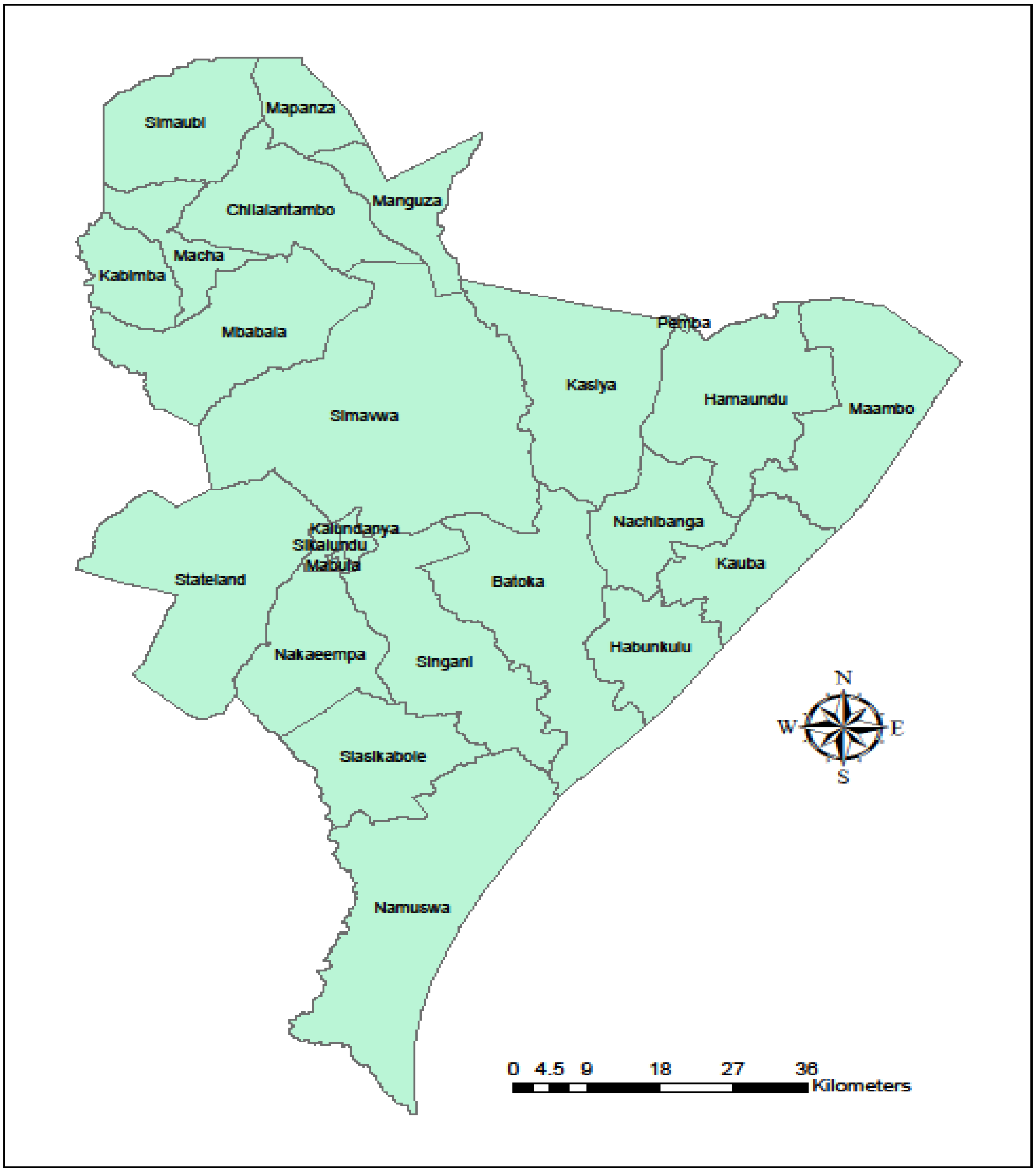


Figure 5: Map of Choma showing divisions at ward level

Table 3: Choma Population Characteristics in 2010

Constituency	Ward	Households	2010 Population		
			Males	Females	Totals
Choma	Batoka	1,260	3,345	3,526	6,871
	Sikalongo	1,455	4,229	4,539	8,768
	Simamvwa	2,106	5,511	5,434	10,945
	Stateland	1,355	3,276	3,247	6,523
	Nakeempa	976	2,988	3,058	6,046
	Moomba	771	1,541	1,572	3,113
	Kulundana	2,856	6,492	6,754	13,246
	Simacheche	1,959	4,155	4,176	8,331
	Sikalundu	1,966	5,465	5,642	11,107
	Mubula	4,491	9,840	10,611	20,451
	**Singani*	*1,585*	*4,030*	*4,071*	*8,101*
	Siasikabole	1,414	3,880	4,126	8,006
	Namuswa	2,127	5,290	5,682	10,972
Constituency Total		**24,321**	**60,042**	**62,438**	**122,480**
Mbabala	Simaubi	2,036	5,806	6,090	11,896
	Mapanza	984	2,747	2,961	5,708
	Mang'unza	992	2,748	2,979	5,727
	Chilalantambo	1,649	4,516	4,851	9,367
	Macha	1,328	3,760	4,450	8,210
	Kabimba	348	919	989	1,908
	**Mbabala*	*2,490*	*6,791*	*7,175*	*13,966*
Constituency Total		**9,827**	**27,287**	**29,495**	**56,782**
Pemba	Kasiya	2,037	5,841	6,137	11,978
	Pemba	513	1,058	1,220	2,278
	Hamaundu	3,264	8,625	9,298	17,923
	Maambo	2,135	5,986	6,355	12,341
	Kauba	1,270	3,339	3,697	7,036
	Habunkululu	809	2,030	2,296	4,326
	Nachibanga	1,557	4,278	4,758	9,036
Constituency Total		**11,585**	**31,157**	**33,761**	**64,918**
Choma Grand Total		**45,733**	**118,486**	**125,694**	**244,180**

Source: Adapted from CSO (2010)

Three (3) seasons can broadly be identified in the region:

- Warm wet season (November – April), with average temperatures of 27-30°C
- Cool dry season (May-July), with average temperatures of 16-27°C
- Hot dry season (August-October), with average temperatures of 27-30°C

At a local level, Southern Province experiences a subtropical type of climate despite it being in the tropics (Archer, 1971). Choma is broadly representative of conditions found in drier parts of Zambia, especially Southern Province. The climate is strongly seasonal with cool dry season

(April to August), a hot dry season (September to October) and a warm wet season (October and April). The country around Choma lies at approximately 1100m to 1300m altitude, the so-called African surface (Dixey, 1955). In December, January and February rainfall exceeds potential evaporation and the surplus being 202mm. Thus, if the infiltration rate is too low to absorb heavy showers or the moisture storage capacity is too low to store infiltrated rain, there will be runoff. Initially, runoff is accompanied by the risk of erosion, then percolation with the risk of leaching. The rainy season extends from October/November to March/April. July is the driest month with zero mm average rainfall. December/January are the wettest months with total seasonal rainfall of about 805mm. Therefore, Choma occurs in a zone of medium rainfall. The mean annual temperature is 18.3°C with daily temperature ranging from 12.6°C in July to 22.1°C in October. The mean daily maximum temperatures for the year is 26.6°C ranging from 22.7°C in June to 31.2°C in October. The mean daily minimum temperature for the year is 10.9°C with daily values ranging from 3.3°C in July to 16.5°C in December. The average sunshine hours per year is 8.1 hours.

3.4.2 Soils

AER II is divided into two sub-regions based on the soil characteristics of the different divisions, AER IIa and AER IIb. *AER IIa* is largely made up of the central sandveld plateaux of Zambia. This plateaux contains soils of mainly Haptic Lixisols (Brammer, 1973; FAO, 1973), Haptic Luvisols and Haptic Acrisols (Brammer, 1973) . These sandveldt soils are only moderately acidic and hold nutrients fairly well under moderate rainfall conditions (Brammer, 1973). The region supports agriculture of different crops such as sorghum, maize, ground nuts cow peas, and many others. *AER IIb* constitutes the western plateau hence largely made of the Kalahari sands and the Zambezi flood plains. This division of AER II contains Ferrallic Aresols which are infertile and largely contains course sands. This division supports some agriculture of some maize varieties and sorghum on the uplands. In the flood plain, rice, maize and sorghum are grown.

On the other hand, the soils in Choma are brownish to reddish yellow with a fine texture. Around the drainage basins soils are usually dark in colour and they are also sticky. The brownish yellow to reddish yellow soils is classified by the Food and Agriculture Organization (FAO, 1973) as *haplic acrisols.* The dark sticky soils around most drainage and flooded areas are referred to as *vertisols.* These soils are poorly drained and have a high available water capacity of between 80mm and 200mm. With good management these soils have a high potential for being ideal soils for grain cultivation.

3.4.3 Vegetation

The present vegetation is cultivated land, fallow or secondary bush. To a certain degree, natural vegetation is found in the *dambos*, but cattle grazing modify even this vegetation. The natural upland vegetation is *miombo* woodland with *Julbernadia globiflora, Brachystergia longifolia, Uapaca kirkiana, Burkea africana, Parinari curatellifolia* and occasional *Albizia antuneziana* trees; and *Hyperrhaenia newtonii, Hyperrhaenia rufa, Hyperrhaenia filipendula, Eragrotis sp., Pogonarthia sp., Dactyloctenium sp*. among other grasses. Some well grown *Brachystergia spiciformis* are observed where the soil depth is sufficient. Other tree species include *Eucalyptus sp., Acacia sp.,* Combretum *sp., Terminalia sp.* and *Piliostigma thoningii.* In the *dambos Loudetia sp., Setaria sp., Eschinochloa sp., and Hyperrhaenia dissolute* are the most common grasses. At the *dambo* fringe *Protea sp.* shrubs seem to occur frequently. The termite mounds have more typical dry land vegetation e.g. *Euphorbia candelabra.*

3.4.4 Topography

The terrain in AER II varies from hilly to flat flood plains and from dense woodland to vast grass plains. Aregheore (2006) reported that Zambia has three main topographical features: Mountains with altitude of at least 1500m; plateau with altitude ranging from 900m to 1500m; and lowlands with altitude ranging from 400m and 900m. The country is on the great plateau of Central Africa at an average altitude of 1200m though Advarneg Inc (2007) said that most landmass lies between 910m and 1370m above sea level. Part of this Great Central African Plateau lies in AER II. In the Central and Eastern provinces, the Muchinga Mountains exceed 1800m in height although most rivers and valleys are found in areas below 610m (Ngoma, 2008). AER II is generally a plateau with average altitude of about 1300m and has no major valleys and/or mountains.

3.4.5 Drainage

AER II is traversed by a number of major rivers such as the Zambezi, Kafue and Luangwa rivers. The region also has got many streams traversing besides the major rivers. However, in the study town-Choma- there are no major rivers or perennial streams, which traverse the town. However, Nkanga River, which is usually flooded during the rainy season, provides the main drainage systems in Choma town. It is on this stream that the Choma dam is constructed. The dam provides Choma residents with both domestic water and fishing grounds. Munzuma dam is also a source of domestic and even commercial water for Choma residents. Several other streams which rarely survive the dry season include: Kabwesha, Semahwa, Munzumanene and Nkanga.

3.5 Socio-Economic Activities

Agriculture provides the major economic activity for people in AER II. The bulk of food and cash accruing to most people in the region is from maize being the most cultivated food crop. Today, Eastern Province is the largest maize producer in Zambia, followed by the Southern and Central provinces (JAICAF, 2008) all located in AER II. Other provinces only yields small amounts of crop production (Table 4).

Table 4: Percentage Production of Some Major Crops by Province, 2002-2003

	PROVINCES									
Crop	Central	Copperbelt	Eastern	Luapula	Lusaka	Northern	N-Western	Southern	Western	Total
Maize	19.2	8.2	32.2	1.9	2.4	7.8	4.7	19.5	4.1	100
Sorghum	22.3	14.1	5.9	2.6	0.1	10.4	17.9	10.3	16.4	100
Millet	6.3	0.2	2.2	6.0	0.1	55.7	0.9	12.0	16.5	100
Rice	0.7	0.2	48.9	3.2	0.0	32.6	0.2	0.0	14.1	100

Source: Agricultural and Pastoral Production (2004) from JAICAF, 2008.

Provincial unit yield in the Western Province is usually less than the average 1.5-2.0 t/ha recorded in most provinces because the province is not suited for rain-fed cultivation of maize due to the lowest rainfall in the country. Production in most provinces had been stagnant due to the fact that smallholders cannot afford chemical fertilizer and new hybrid varieties and use recycled seeds instead with small inputs (JAICAF, 2008). Based on size of holding, the FAO (1998) identified three categories of farmers: small-scale (1-10 ha), medium scale or emergent (10-40 ha), and large-scale farmers (more than 40 ha). AER II houses all these types of farmers.

Small-scale farmers are estimated at 92 percent while medium and large-scale farmers make up eight percent. While different food crops such as groundnuts, beans, maize, cassava, sweet potatoes and Irish potatoes are grown in different parts of the country and different parts of AER II, maize is grown as the basic staple food for Zambia's people (Saasa, 2003; Ngoma, 2008). It uses about 70 percent of total cropland (The World Bank, 2003). Despite the agriculture sector being the most important sector in the county, less than 5% of the cropland is under irrigation, indicating that more than 95% of cropland is rain-fed (Dorosh *et al* (2007). Hence most of the agriculture in the country depends on the weather conditions for the particular season.

The major economic activity in Choma District is agriculture. Farmers practice both arable and pastoral farming on a small scale although there are a few commercial farmers. Agricultural production is oriented towards local needs and only small amounts of farmers' produce are sold on the markets. Some farmers and other residents within Choma town are involved in mixed farming, vegetable gardening and trading. The district is largely a cattle production area and it is not strange to see cattle in the Central Business District. The Makalanguzu market, which is the main market, is well stocked with agricultural products, which are brought from surrounding areas.

CHAPTER FOUR

METHODOLOGY

4.1 Introduction

This chapter presents the methodology used in data collection and highlights the primary and secondary sources data and outlines data analysis conducted on both qualitative and quantitative data collected. Finally, limitations of the study are outlined.

4.2 Data Sources

The study utilized two sets of data sources; secondary and primary sources. These are discussed below.

4.2.1 Secondary Data

This study used annual temperature and rainfall data for selected meteorological stations in AER II obtained from the Zambia Meteorology Department (ZMD) as well as published archival rainfall data (1910-1970) (ZMD, 1972). The analysis was based on meteorological years which start from 1 August and end on 31 July of the following year. The data for maize varieties in the AER II was obtained from the Zambia Agriculture Research Institute (ZARI) under the Ministry of Agriculture and Cooperatives (MACO) and the private seed breeding companies that included ZAMSEED, SEEDCO, PANNAR and MRI Seed. Post-harvest reports for small-scale famers were obtained from the Central Statistical Office (CSO). Some internet sources were also used.

4.2.2 Primary Data

Primary data was collected through interviews by the use of a semi-structured interview schedule prepared for small-scale farmers. A small-scale farmer refers to a farmer who cultivate between 0.5 to 9 hectares of customary land and often use their own family labor for farming (Siegal and Alwang, 2005). This group of farmers was selected as they are the most vulnerable to the impacts of climate variability. The data collected using this instrument from small-scale farmers dealt with their perception of climate variability and its impacts in the area, their coping strategies and adaptation measures to impacts of climate variability. Furthermore, information on the government position on climate change was obtained from key informants by interviews with officials from the Department of Agriculture and the Climate Change Facilitation Unit of the Ministry of Tourism, Environment and Natural Resources (MTENR). Data collected from seed breeding companies related to the recommended varieties for AER II and the contributions of the companies to seed breeding in Zambia.

4.3 Sampling

4.3.1 Meteorological Data

The rainfall and temperature data for all the available stations in AER II was utilized. The selection of the meteorological (MET) stations in AER II was done on the basis of data availability for the meteorological years 1910 to 2009 for rainfall and from 1945 to 2009 for temperature. The difference in periods for temperature and rainfall was due to the fact that temperature measurements were not done in all the stations in AER II before 1945. The first station to record temperature was Chipata in 1945. However, both periods (for rainfall and temperature) were long enough to establish the patterns, trends and variations in climatic conditions in AER II. Furthermore, climate data analysis requires very long data sets, hence the longer the data set the more accurate the results and, in terms of decadal analyses the shorter the period the less the reliability of the decadal trends obtained. This fact determined the selection of a longer period for rainfall as data was available and made it possible to establish decadal trends requiring a long period of time. The period from 1910 to 2009 only captured about 10 decades while the period from 1945 to 2009 captured about 6 decades. The rainfall data before 1945 was used to establish trends and rates of rainfall change in that period while comparative analyses involving temperature and rainfall data were done in the period 1945 to 2009.

Thirteen (13) stations were sampled for rainfall and these included Lusaka, Lundazi, Chipata, Choma, Kabwe, Kalabo Kaoma, Sesheke, Senanga, Mongu, Mumbwa, Petauke and Monze. Similarly, thirteen (13) stations were sampled for temperature and these included Lusaka, Chipata, Choma, Sesheke, Senanga, Kabwe, Kaoma, Mongu, Mumbwa, Petauke, Monze, Kafue and Chilanga. These 13 stations were used in establishing the annual rates of rainfall and temperature change over the selected periods. Of the 13 selected stations eleven (11) had both rainfall and temperature time series data for the sampled periods (i.e. Lusaka, Chipata, Choma, Sesheke, Senanga, Kabwe, Kaoma, Mongu, Mumbwa, Petauke and Monze). Analysis of data for these towns was used for comparisons among themselves. However, rainfall data for Lundazi and Kalabo was only included when determining the annual rate of change for rainfall while temperature data for Kafue and Chilanga were only included when determining the annual temperature rate of change because these towns did not have time series data for both rainfall and temperature. Towns which had a larger part of its area covered in AER II with only a small part in another AER as was Sesheke, Senanga, Petauke and Kafue were included in the sample as they were assumed to exhibit characteristics of AER II.

4.3.2 Maize Seed Breeders

The major stakeholders in climate change and seed breeding in Zambia interviewed included seven senior officials from CCFU, MACO, ZARI, ZAMSEED, MRI SEED, PANNAR SEED and SEEDCO. Purposive sampling for selection of sites was used in order to ensure that two sites on the opposite sides of the study town were selected. Hence Mbabala and Singani study sites were selected as they were on the opposite sites of Choma town. The need for sites in the northern and southern areas of the town was necessary to ensure diversity of responses as it was assumed that the further the sites are from each other, the more independent they were of each other.

The selected study sites (Mbabala and Singani) were wards in the sample town (Choma) and hence the selection of the households for sampling was done at ward level. This was because of the easy availability of the household information at this level rather than the village level. It was easier to find the information on all the households in Singani area from the local authorities (Choma Municipal Council), Central Statistics Office and the traditional authorities rather than looking for this information from all the small villages in the area. Therefore a total of 112 households where successfully interviewed from Singani and Mbabala study sites with 83 coming from Mbabala while 29 were from Singani. The 112 households were selected from a total of 4075 households in Mbabala (2490 households) and Singani (1585 households) (Table 3). This sample was large enough to establish the adaptation and coping strategies by small-scale farmers in the area as well as establish their preferred maize varieties. Furthermore, the sample size was amenable to statistical testing on account that normal distribution was assumed (i.e. the assumption of normality of sample can be done for samples of *n* greater than 30)(Bryman 2004).The sample was also adequate for use of semi-structured interview schedules rather than questionnaires in order to minimize problems of non-response and allowed the researcher to probe further in cases where more information was needed. Farmers (small-scale) in the study sites were randomly sampled at ward level using the registers collected from traditional authorities in the sample sites. The names of farmers shuffled in an enclosed non-transparent box were picked at random and the 112 picked (83 from Mbabala and 29 from Singani) formed the random sample.

The interviews with the randomly 112 selected respondents were conducted with household heads and older children in cases where these older children had their own individual farms. Spouses were also allowed to be part of interview groups as they could remember the maize varieties planted and methods of coping that were conducted by the families in times of crop loss due to droughts and/or floods, at times were even better than the household heads. Furthermore, interviews were conducted with the female household heads.

4.4 Data Analysis

Given the complexity and uncertainty of issues involved in climate analysis and scenario creation, a cautious approach would be to determine the variability in the past before projecting the results and expected implications into the future. To be beneficial to society the analysis should not only involve the statistical and positivistic analysis of the variability but should include the social and institutional perspectives to uncover the depth of the impacts on the agriculture sector and particularly the seed breeding industry and the small-scale farmers. In view of this both quantitative and qualitative techniques were used to analyze the collected data.

4.4.1 Quantitative Analysis

Rainfall and temperature variability was analyzed using the Coefficient of Variation (CV). An analysis of decadal CVs was further carried out to determine the decadal climatic variations in AER II. The calculated CVs presented as percentages using the formula:

$$\%CV = (StDev/X_m)\ 100 \quad \ldots\ldots(1)$$

Where CV=Coefficient of Variation, StDev=Standard Deviation, X_m=Mean

When calculating the 11 year running CVs the computation involved using the running means for consecutive 11 years and the running standard deviations for consecutive 11 years. These consecutive 11 years were overlapping i.e. if the first set of 11 years start from 1910 to 1920, the next set was starting from 1911 to 1921 and so on. Both the mean (X_m) and average standard deviations (StDev) were moving for each 11 year period when calculating the moving CV. When presenting rainfall and temperature variations, the annual rainfall and temperature data was first converted into percentage CVs. These percentage CVs were then used to plot 11-year rainfall and temperature CVs for each selected station in AER II. Hence this 11-year running rainfall and temperature CVs were moving averages calculated from percentage CVs plotted and these calculations utilized the running standard deviations and the running means for each 11-year period to come up with the running CVs presented.

The variations in the observed rainfall and temperatures were subjected to the statistical technique of Analysis of Variance (ANOVA). This test was used to analyze the significance of the variability in the means of decadal observed rainfall and temperatures in AER II from 1910 to 2009 and 1945 to 2009, respectively. The hypothesis of no significant difference in means of decadal means for rainfall and temperature was tested at 0.1 level of significance. The formula used for the analysis is:

$$F = \frac{\text{Variation between the decades}}{\text{Variation within the decades}}$$

Where the variation between the groups was the variation between the rainfall classes; 1910-1919, 1920-1929, 1930-1939, 1940-1949, 1950-1959, 1960-1969, 1970-1979, 1980-1989, 1990-1999, 2000-2009 and/or the temperature classes 1945-1954, 1955-1964, 1965-1974, 1975-1984, 1985-1994, 1995-2004 and the variation within the groups was the rainfall variation and/or temperature variation within each of these classes of years. Variation between the classes was calculated using the formula (Ebdon, 1985):

$$S^2_b = \frac{\sum n\,(x_m - x_{Gm})^2}{k-1}\,, \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where S^2_b= variance between the classes, **n**=number of rainfall/temperature readings in each period, **k** =Number of sample classes, x_m=mean for each sample period, x_{Gm}=Grand mean of all the rainfall/temperature values.

Variation within the classes was calculated as follows (Ebdon, 1985);

$$S^2_w = \frac{\sum\sum(x-x_m)^2}{N-k} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where S^2_w=variance within the sample periods, **N**=total number of all rainfall/temperature readings in all the periods, **k**=number of sample periods, X_m=mean for each sample period, **x**=Rainfall/ temperature readings.

The F test value was then calculated as follows (Bluman, 2007):

$$F_{cal} = S^2_b/S^2_w \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The basis for interpretation was to reject the formulated null hypothesis if F_{cal} was greater than the F_{crit} (F-value was obtained from the critical tables) at 0.1 level of significance or if the P-value was greater than the level of significance. This quantitative analysis was applied to both temperature and rainfall data separately.

The annual rate of change for the rainfall in AER II from 1910 to 2009 and temperature from 1945 to 2009, was calculated using the regression analysis. The regression equation (5) was used to calculate the rate of change:

$$X = a + bY_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

where Y= Year, a= y-intercept, b= annual rate of rainfall change, X_1=rainfall values

This equation was applied to all the sampled towns in AER II to determine the individual rates of change for the rainfall and temperature in these towns. The average change for all the stations was then calculated as it represented the average annual rate of change for the region.

4.4.2 Qualitative Analysis

Given the inherent uncertainty in climate variability, a robust qualitative approach should be employed to complement and enrich the statistical analysis undertaken. The qualitative tools which were used in this study included a comprehensive review of the climate variability in the world, Africa and Zambia. Furthermore, literature review on agriculture and the seed breeding industry in Zambia was undertaken. Interviews with small-scale farmers revealed their adaption measures and coping strategies to impacts of climate variability. Appropriate case studies were reviewed to highlight the impacts and implications of climate change on Zambia's seed breeding industry.

The collected data on climate variability, agriculture and seed breeding given by ZAMSEED, MRI Seed, PANNAR Seed, SCRB/ZARI and SEEDCO were analyzed based on major themes such as climatic requirements, potential yields, adaptability and stability. Finally, scenarios of climate variability were constituted to show the implications on maize growing by small-scale farmers in AER II.

4.5 Limitations of the Study

The study encountered a number of limitations during data collection namely:

- Many meteorological stations in AER II had not been recording either temperature or rainfall measurements. This reduced the number of study stations sampled. Furthermore a number of stations previously recording weather data had closed down or made recordings infrequently attributed to limited staffing levels.
- High cost of field work made it difficult for the researcher to undertake longer data collection exercise. This was compounded by delayed release of the research funds by the sponsors (UNZA) which limited the time for field data collection.

4.6 Assumptions

For this study, it was assumed that maize production was only affected by the influences of rainfall and temperature with other factors held constant.

The next chapter provided detailed analyses and the results of the study.

CHAPTER FIVE

DATA ANALYSIS AND RESULTS

5.1 Introduction

This chapter presents data analysis and results in line with the study objectives. The data and results for objective (1) were presented first followed by those for objectives 2-4 as described below.

5.2 Climatic Variations in AER II

Rainfall and temperature variations were calculated by the use of the coefficient of variation (CV). The results for occurrence of climatic variations and their significance were presented. The Analysis of variance was used to determine the significance of the rainfall and temperature variations observed using the CV from the years 1910 to 2009 and 1945 to 2009, respectively.

5.2.1 Rainfall Variations in AER II, 1910-2009

The decadal CVs for the 11 stations sampled from AER II were calculated and expressed in percentages (Table 5). Sesheke in the southern Western Province had the highest CVs (35.5 to 52.2) while Mongu in the northern part of the Western Province exhibited relatively lower CVs. Increased rainfall CV trends represented increased rainfall variability while reduced CV trends represent reduced rainfall variability. Therefore, high CVs indicated an area's tendency towards a single unusually wet year followed by usual extreme dry years. Table 5 presents the percentage decadal rainfall CVs for the 11 meteorological stations sampled in AER II.

In order to determine the trends in rainfall CVs over the period 1910 to 2009, the mean annual rainfall data collected from ZMD was converted into percentage CVs. The running CVs were calculated using the running standard deviations and the running means for the same 11-year period. When the annual trends (rather than decadal) were considered (Figure 6), all the towns in AER II exhibited positive rainfall trends from 1940 to 1950. Furthermore, with the exception of Sesheke, CVs were lowest in the region before 1940 as the towns showed relatively decreased CV trends up to 1940 when the CV trends started to increase. AER II again experienced relatively stable CVs from the 1970s to the 1980s when the trends started to increase and peaking in the early 1990s characterized by an abrupt increase in CVs there after (Figure 7).

Table 5: Percentage Decadal Rainfall CVs for Selected Stations in AER II, 1910-2009

Class	Lusaka	Chipata	Sesheke	Kaoma	Mumbwa	Mongu	Senanga	Choma	Kabwe	Petauke	Monze
1910-1919		22.8	40.3		23.8	16.7					
1920-1929		13.7	41	18.9	25.3	21.6		25		17.4	
1930-1939		12.5	37.5	21.7	20	28.6	19.9	19.9	22	18.5	
1940-1949	21.7	20	38.8	19.6	19.1	19.3	27.7	22.9	17.7	22.2	29.1
1950-1959	13.2	18.1	43.6	21.7	13.3	16.5	26.8	20.1	18.3	17.8	21.7
1960-1969	26.9	19.4	39.6	22.8	19.2	17.6	23.7	29	27.6	18.9	16.7
1970-1979	29.6	21.4	50	17.8	25.2	18	20.2	30.5	22.3	23.7	22.1
1980-1989	32.2	21.5	35.5	15.8	29.1	20.7	17.7	32.3	14.7	27.3	15.8
1990-1999	28.5	26.3	40.7	16	33.2	23	19	24.7	23.4	22.3	20
2000-2009	18.2	39.8	52.2	24.6	31.8	33.8		32.5	42.2	18.8	21.9

A comparison of the different CV trends among the sampled towns showed that Sesheke had a tendency towards high CVs. Mumbwa and Mongu experienced a steady decrease in CVs until the 1950s when the area started experiencing an increase in CVs. Kabwe and Monze had a steady decrease in CVs until the 1970s when the CVs started steadily rising while Kaoma had stable CVs throughout the study period. Figure 8 provides a comparison of rainfall CV trends for some selected stations in AER II.

The CVs presented in Table 5 and Figures 7 and 8 showed the trends and magnitude of variation. Table 6 presents the actual decadal rainfall data for the 11 selected meteorological stations in AER II. The mean for the decadal rainfall is assumed to represent the average rainfall for that particular area during the particular decade. The CV results in Figures 7 and 8 were corroborated by the decadal rainfall trends in Figure 9 which illustrate the occurrence of deviations in the means of decadal rainfall from the long-term mean. While all the towns have experienced periods of high and low rainfall, the general trend in all the cases has been constant variability below and above the normal, thus, long-term mean for the period 1910 to 2009.

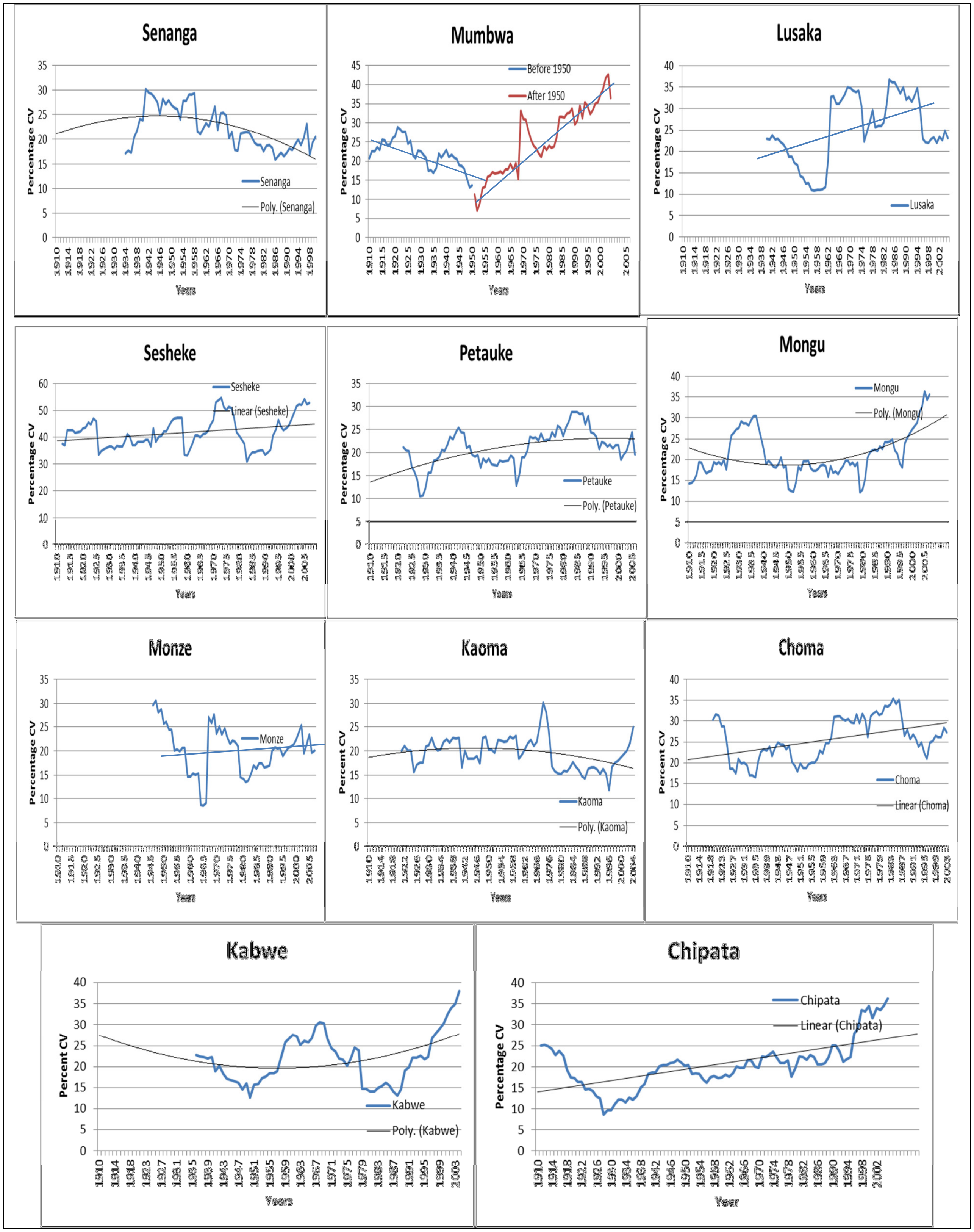


Figure 7: Graphs showing annual rainfall trends plotted from percentage 11-year running CVs for the eleven selected stations in AER II, 1910-2009

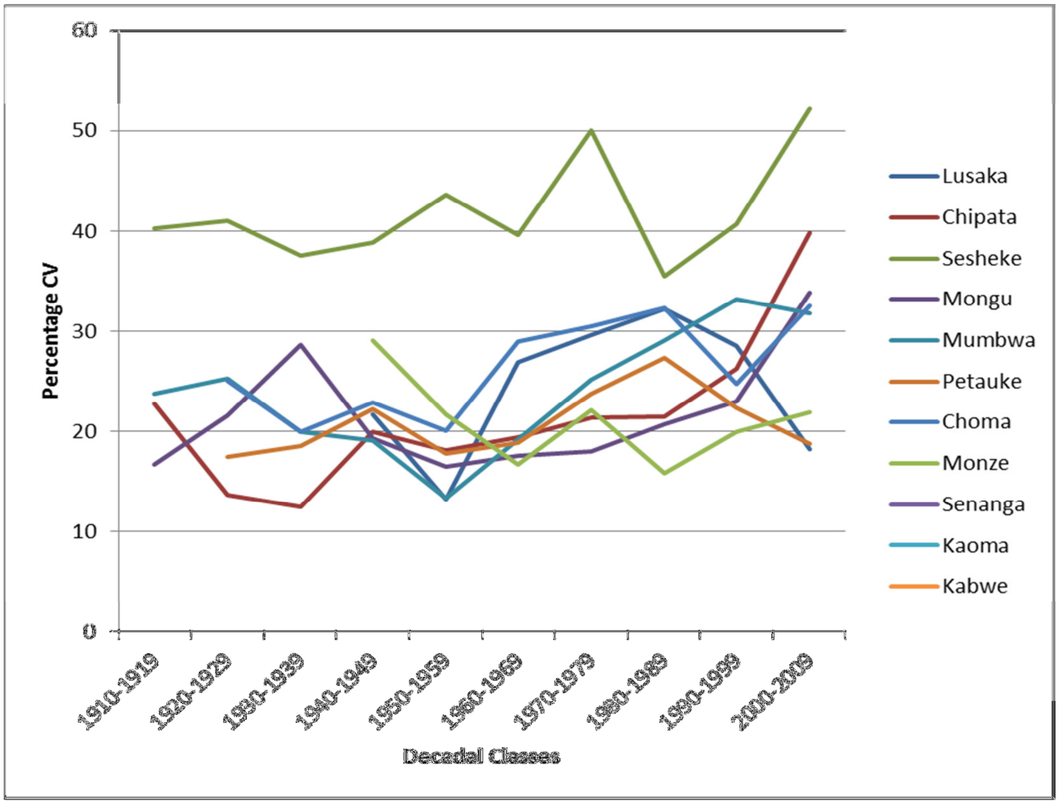


Figure 8: Percentage rainfall coefficients of variation for selected stations in AER II, 1910-2009

Eastern Province had been the wettest over the century with Chipata recording the highest decadal mean (1207mm) for the century between 2000 and 2009 while Monze in Southern Province had been the driest in the region (Table 6).

Table 6: Decadal rainfall data in millimeters per year for selected stations in AER II for the period 1910-2009

Class	Lusaka	Chipata	Choma	Kabwe	Sesheke	Kaoma	Mongu	Senanga	Mumbwa	Petauke	Monze
1910-1919		998.4	909.5		682.4		917.5		811.5		
1920-1929		932.4	801.1		714.4	975.4	1020.3		918.2	1000.1	
1930-1939	1146.8	1002.8	771	864.4	563	969.7	1011.3	794.6	867.4	996.1	
1940-1949	785.6	1036	841.6	903.2	677.4	892.6	884.4	807.5	896.7	851.4	686.3
1950-1959	832.4	1010.1	879.1	1026.5	878.5	1016.2	1061.4	926.3	949.3	1040.3	870
1960-1969	811.3	1048.7	832.2	1014.6	626.4	958.4	955.8	759.4	930.1	964.5	711
1970-1979	728.5	1068.3	839.7	886.9	687.9	872.7	969.9	798.3	964.6	951.1	901.8
1980-1989	792.4	991.2	750.7	847.3	453	848.5	840.5	702.3	884.8	1012.7	688.6
1990-1999	700.0	883.2	703.4	769.7	538	775.8	870.4	733	719.4	861.8	687.9
2000-2009	887.2	1207	809	906.2	588	893.2	987	603.7	811.4	935.5	793.1

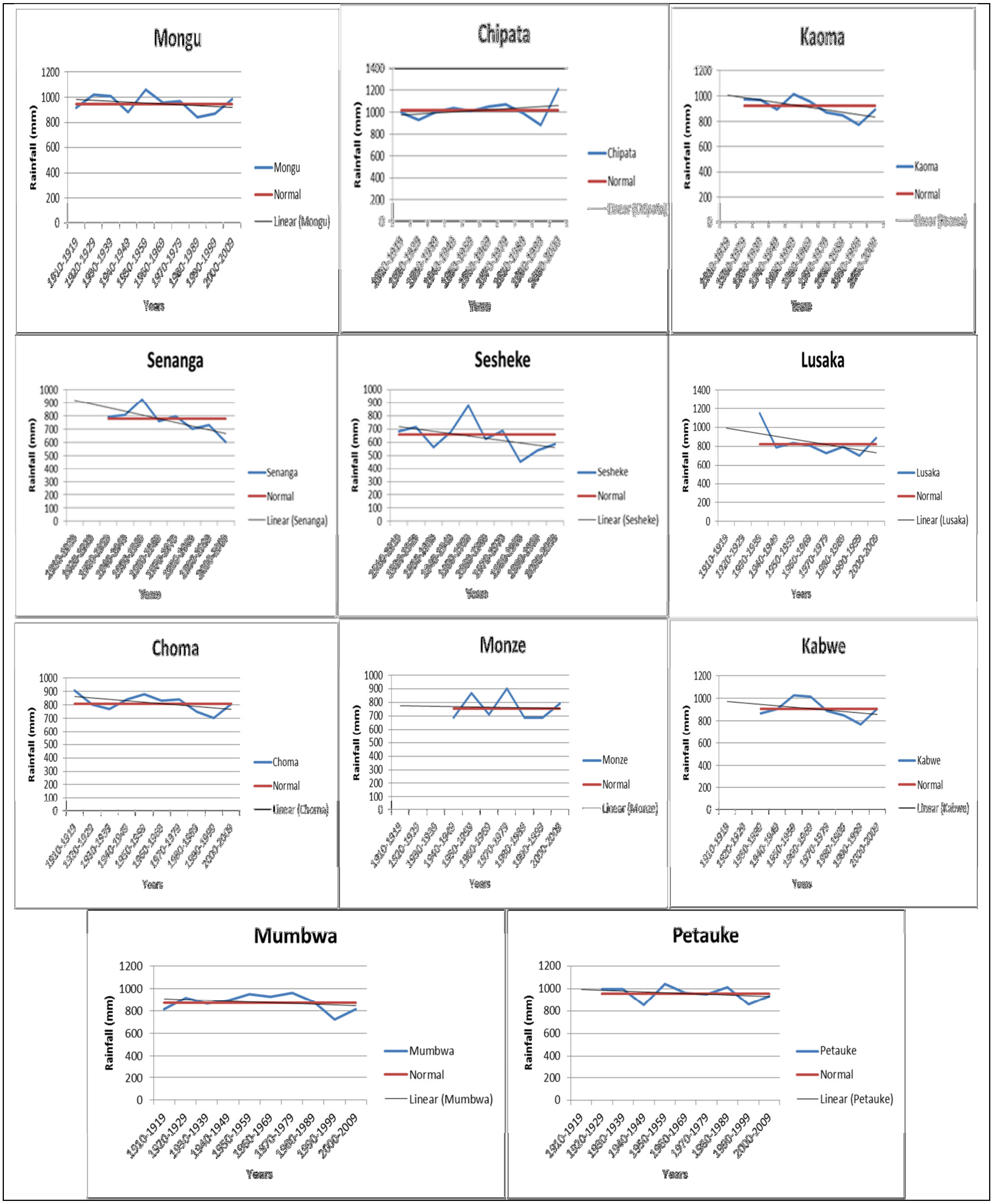


Figure 9: Decadal rainfall variations for the eleven selected stations in AER II, in the periods of record

While most of the decadal graphs were fluctuating about the mean, generally, AER II experienced an abrupt reduction in rainfall during the 1980s as all the graphs showed a decline up to the 2000s (Figure 9).

The rainfall data for each study station was analyzed quantitatively and summaries of descriptive statistics computed (Table 7). Lundazi and Kalabo towns which were omitted from the previous rainfall comparative analyses due to lack of time series data for temperature were included in Table 7 as they were going to be used for estimating the rate of rainfall change in AER II.

Table 7: Rainfall Descriptive Statistics for the Selected 13 Stations in AER II for the period 1910 to 2009

Town	**N**	**N***	**Mean**	**StDev**	**Minimum**	**Maximum**
Lusaka	69	31	819.2	208.5	314.8	1524.5
Chipata	100	0	1017.8	228.5	626.4	1931.7
Sesheke	97	8	660.6	216.9	173.7	1542.0
Kaoma	72	28	923.2	187.8	560.0	1504.2
Mumbwa	97	3	871.2	209.0	398.6	1348.0
Mongu	100	0	946.8	200.6	604.3	1579.5
Senanga	62	38	776.7	194.1	447.8	1422.1
Lundazi	78	22	862.1	184.8	419.1	1356.8
Choma	91	9	805.4	208.8	375.6	1419.5
Kabwe	76	24	903.8	204.6	408.3	1463.3
Kalabo	72	28	887.0	270.1	246.1	1353.3
Petauke	90	10	957.0	202.9	564.5	1402.7
Monze	58	42	752.4	168.1	456.3	1302.0

Notes: N=Non missing values for the sampled period (1910-2009), N*=Number of missing values during the study period and StDev=Standard Deviation

The analyzed data showed differences between towns hence the need to use standardized values in form of CVs for comparison rather than actual rainfall values. Of the eleven towns sampled for the purpose of estimating the annual rates of rainfall and temperature change, only Chipata and Mongu had time series data from 1910 to 2009.

The archival rainfall data was then subjected to the ANOVA test in order to determine the significance of the observed variations. The results showed an F ratio of 2.94 and a P-value of 0.036 (Table 8). Appendix 2 presents the computational details for the analysis of variance.

Table 8: Rainfall Summary Statistics for the ANOVA Test

Source	DF	SS	MS	F	P
Factor	9	307233	34137	2.94	0.036
Error	90	1586016	17622		
Total	99	1893249			

5.2.2 Temperature Variations in AER II, 1945-2009

The decadal temperature CVs for the nine stations sampled from AER II were calculated and presented as percentages. As was the case with rainfall CVs, Sesheke in the southern Western Province had the highest CVs while Mongu in the northern Western Province and Chipata in Eastern Province exhibited relatively lower CVs. Central and Southern provinces exhibited moderate percentage CVs. The 2000-2009 decade experienced the highest variability of the century with many towns in the region exhibiting highest decadal variability with Senanga in the Western Province recording the highest decadal variability of 5.7 (Table 9). Increased temperature CV trends represented increased temperature variability while reduced temperature CV trends represented reduced temperature variability. High temperature CVs indicated that the area experienced unusually high temperatures over a short period before reverting to the usually lower temperatures for the towns of study.

Table 9: Percentage Temperature CVs for selected stations in AER II

Class	Lusaka	Chipata	Sesheke	Kaoma	Mumbwa	Mongu	Senanga	Choma	Kabwe	Petauke	Monze
1940-1949		2	2.2								
1950-1959	1.7	1.7	3.1			1		2.2	1.8	1.4	
1960-1969	2	1.3	3.2	1.9		1.6		1.7	1.8	1.5	
1970-1979	2.6	1.5	2.6	2.1		1.7		2.2	2	2.2	2.2
1980-1989	2.6	1.9	3.3	2.2	2.2	1.6	2.1	2.3	1.9	2.2	2.6
1990-1999	2.8	2.1	3.3	2.1	3.3	1.7	2.1	2.3	2.9	2	3.2
2000-2009	2.3	3.1		1.5	3.3	1.7	5.7	2.4	3.5	2.3	3.1

In order to determine the trends in temperature CVs over the period 1945 to 2009, the mean annual temperature data collected from ZMD was converted into percentage CVs. It is these individual annual CVs (rather than decadal) which were converted into 11-year moving averages so as to determine the trends in annual variations. As was the case for rainfall, the temperature running CVs were calculated using the running standard deviations and the running means of the calculated percentage annual CVs. Mongu in Western Province exhibited steadily increasing annual CVs trend until the 1980s when it abruptly reduced and increased again. Temperature CVs in Lusaka Province followed a similar pattern to that of Western Province with increasing trend up to 1980 when it abruptly reduced. Choma and Kaoma had exhibited relatively stable variability over the century although seasonal variations have been evident but these variations have been occurring within a specific range over time (1.7-2.4). Chipata on the other hand had reduced annual CV trend before 1970 after which it increased. Figure 10 shows the annual temperature CV trends for the selected towns in AER II.

Generally, with the exception of Kaoma, the towns in AER II had increased temperature CV trends between 1945 and 2009. Senanga had the highest variability (5.7) in the 2000-2009 decade even though it showed steady variability from 1980 to 2000 (2.1). Chipata in Eastern Zambia experienced reduced CV trends which abruptly increased after 1973. The increase escalated during the 1980s. A comparison of the different CV trends among the selected towns showed that Mongu experienced relatively stable CVs after the 1970s while Kabwe had the highest increase in CVs after the 1980s. Choma in the Southern Province showed moderate CVs with a relatively stable trend since the 1980s while Chipata in Eastern Province exhibited increased CVs especially in the last decade. Figure 11 provides a comparison for the percentage temperature CV trends in AER II for selected study stations.

Western and Eastern provinces had been the hottest in AERII especially over the last decade with Mongu and Petauke recording high mean temperatures (23.5ºC and 23.3ºC, respectively) (Table 10).

Figure 10: Graphs showing trends in annual CVs plotted using the 11-year running temperature CVs for the eleven selected stations in AER II from 1945-2009

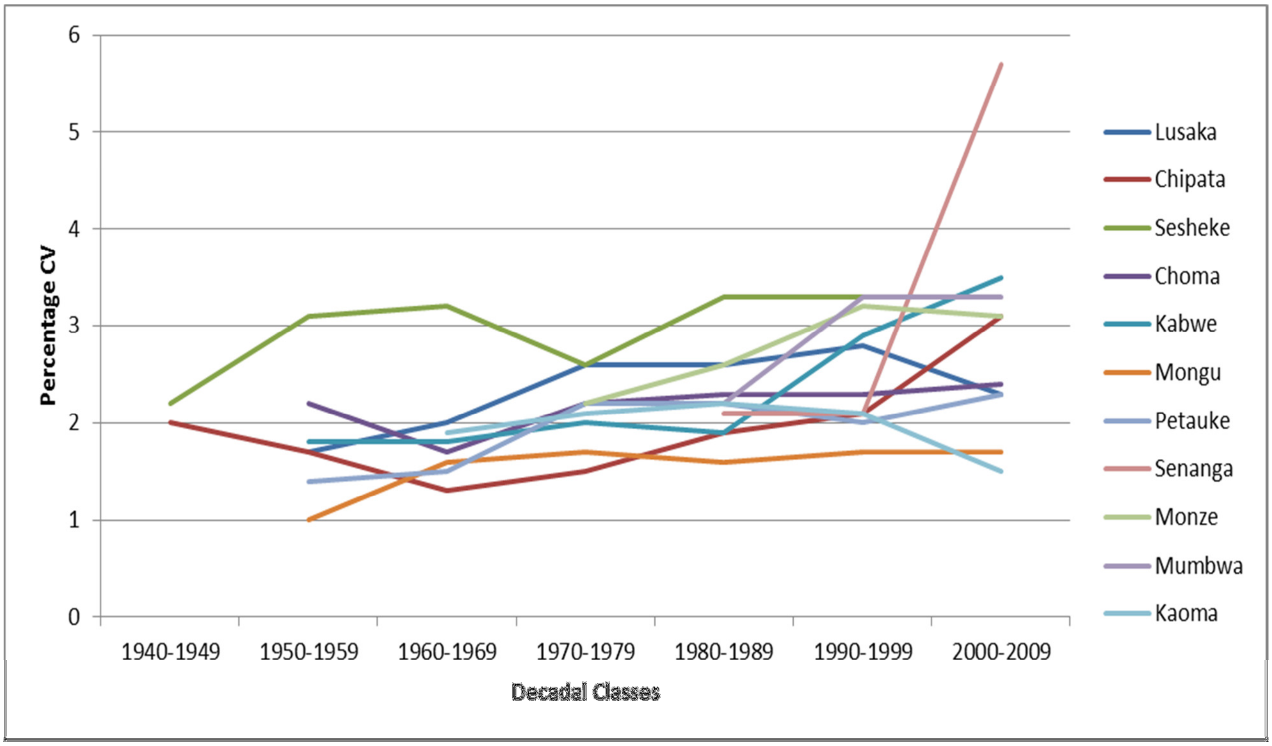


Figure 11: Percentage Temperature CVs for selected stations in AER II, 1945-2009

Table 10: Decadal Temperature Data in Degree Celsius (ºC) for selected towns in AER II for the period 1945-2009

Class	Lusaka	Chipata	Choma	Kabwe	Sesheke	Kaoma	Mongu	Senanga	Mumbwa	Petauke	Monze
1940-1949		22.3									
1950-1959	20.5	22.1	19.5	20.6	21.5		22.2			21.9	
1960-1969	20.3	22.1	18.8	20.5	21.3	21.1	22.2			22.1	
1970-1979	20.3	22.1	19.1	20.5	21.4	21.2	22.6	22.8	21	22.3	20.7
1980-1989	20.4	22.5	19.6	20.9	22.2	21.7	23	23	21	22.6	21.3
1990-1999	21.2	23.1	20.1	21.3	22.3	21.9	23.4	23.4	21.2	22.9	21.6
2000-2009	21.1	22.1	20.3	21.7	22.1	22.4	23.5	22.8	21.3	23.3	22.1

The CVs in Figures 10 and 11 were corroborated by the temperature trends in Figure 12 which illustrate the occurrence of deviations in the means of decadal temperature from the long-term mean for the period 1945 to 2009.

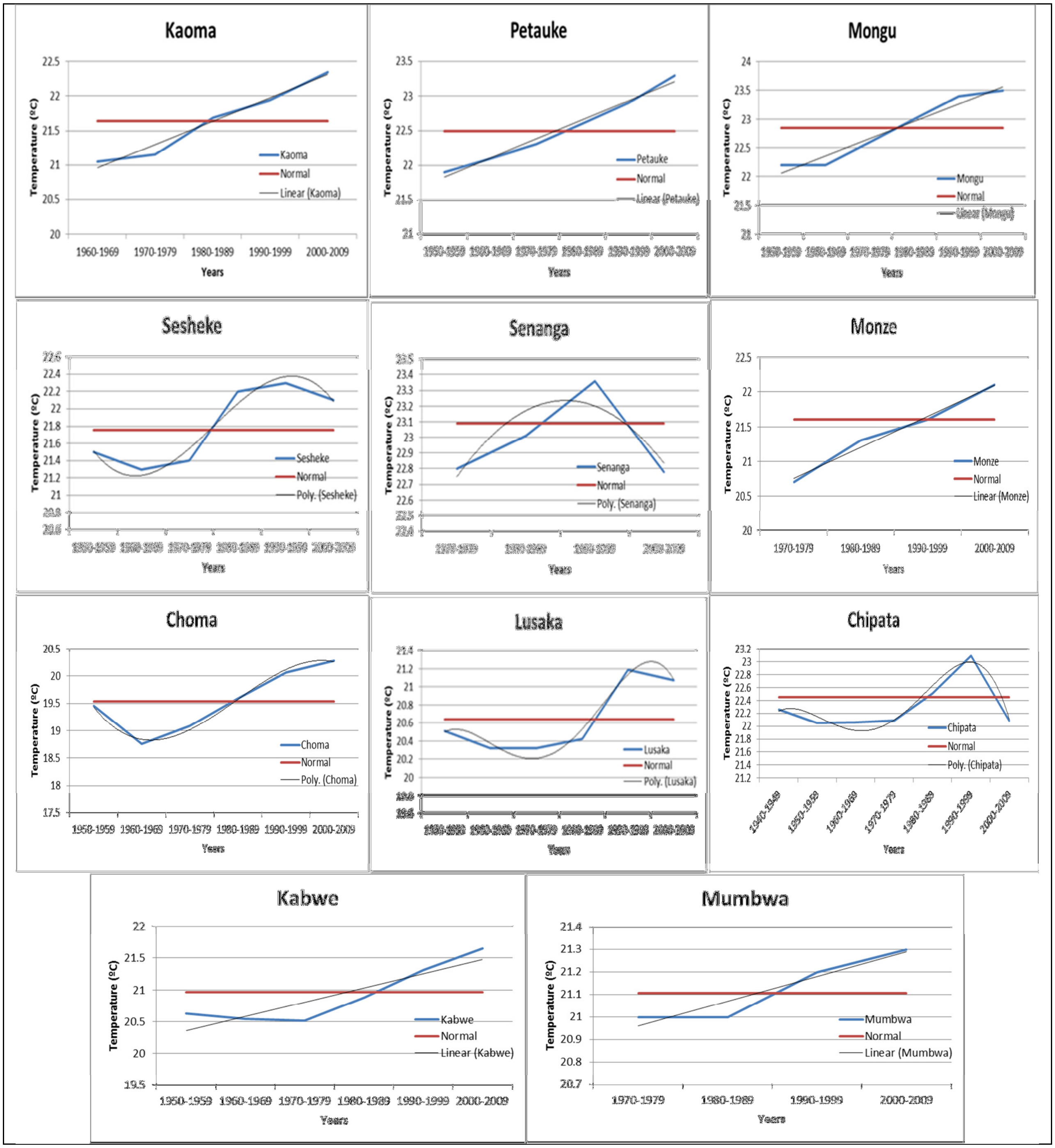


Figure 12: Decadal Temperature Mean for the eleven Selected Towns in AER II

Generally, Figure 12 shows a decadal increase in temperatures in all the towns in AER II indicated by sharp upward turns in the decadal temperature curves after the 1980s. Before the 1980s temperatures were all below the long-term mean until a sudden increase occurred in the 1980s when temperatures rose above the long-term mean for all towns.

The temperature data for each study station was analyzed quantitatively and summaries of descriptive statistics were computed (Table 11). Chilanga and Kafue towns which were omitted from the previous temperature comparative analyses due to lack of time series data for rainfall (though they had temperature data) were included in Table 11 as they were going to be used for estimating the rate of temperature change in AER II. Note that the period of temperature measurements was from 1945 to 2009 as compared to 1910 to 2009 for rainfall. With the exception of Chipata, all the sampled towns had missing temperature values (N*) and they all differed in periods of record used for analysis (N). Hence the mean and standard deviations were standardized in form of CVs (Equation 1) to provide a basis for comparison between the different towns.

Table 11: Temperature Descriptive Statistics for selected towns in AER II

Variable	**N**	**N***	**Mean**	**StDev**	**Minimum**	**Maximum**
Sesheke	54	9	21.753	0.706	20.000	23.200
Mumbwa	32	33	21.106	0.622	19.950	22.700
Choma	60	5	19.538	0.661	18.200	21.100
Kabwe	54	11	20.960	0.688	19.350	23.800
Chipata	65	0	22.448	0.589	21.200	23.900
Senanga	26	39	23.088	0.611	21.200	24.400
Monze	31	34	21.606	0.693	20.550	23.400
Kaoma	47	18	21.645	0.641	20.500	23.300
Petauke	60	5	22.493	0.624	21.350	24.100
Mongu	55	10	22.844	0.605	21.700	24.050
Lusaka	60	5	20.637	0.598	19.650	22.250

Notes: N=Non missing values for the sampled period (1945-2009), N*= Number of missing values during the study period and StDev=Standard Deviation

The archival temperature data was then subjected to ANOVA test in order to determine the significance of the observed variation. The results showed an F ratio of 15.17 and a P-value of 0.001 (Table 12). Appendix 3 presents the details of the computation for the temperature analysis of variance

Table 12: Temperature Summary Statistics for the period 1945-2009 for AER II of Zambia

Source	DF	SS	MS	F	P
Factor	5	17.261	3.452	15.17	0.001
Error	54	12.287	0.228		
Total	59	29.548			

Having established the occurrence of rainfall and temperature variability in AER II, there was a need to establish the direction and rate of rainfall and temperature variability determined by the ANOVA. Table 13 presents the results for both the direction and rate of change for rainfall and temperature in AER II among the sampled towns. The table also includes towns which were previously omitted in previous sections for lack of either rainfall or temperature data. Here they were included so as to have as many stations in order to get meaningful results. The inclusion of towns like Lundazi and Kalabo for rainfall and Kafue and Chilanga for temperature had little effect on the results because the rates of change were merely used to determine rate of change over time in AER II and not for comparison purposes. This accounts for the 13 stations used for both rainfall and temperature analysis in this table as compared to the 11 stations which were used in other tables and graphs.

Table 13: Annual Rate of Change for Rainfall and Temperature for Selected Stations in AER II for the Periods 1910 to 2009 and 1945 to 2009 at 0.1 Level of Significance

Town	**Rate of Rainfall Change**		**Rate of Temperature Change**	
	Rate (mm/year)	**Period**	**Rate (ºC/year)**	**Period**
Lusaka	-0.39	1939-2009	0.016	1950-2009
Lundazi	-1.44	1927-2008	-	-
Chipata	0.79	1905-2009	0.020	1945-2009
Choma	-0.75	1918-2008	0.024	1950-2009
Kabwe	-1.65	1933-2008	0.022	1950-2009
Sesheke	-1.09	1910-2009	0.018	1950-2007
Kalabo	-3.01	1921-2008	-	-
Kaoma	-1.89	1921-2008	0.036	1962-2009
Mongu	-0.23	1905-2009	0.031	1955-2009
Senanga	-2.51	1932-2008	0.005	1979-2009
Mumbwa	-0.72	1905-2008	0.012	1978-2009
Petauke	-0.71	1920-2009	0.027	1950-2009
Monze	-0.64	1945-2009	0.040	1978-2009
Kafue	-	-	0.020	1957-2009
Chilanga	-	-	0.029	1962-2009
Average Rate	**-1.09**		**0.023**	

A dash (-) indicate lack of data for either rainfall or temperature for that particular station

With the exception of Chipata (0.79mm) all the towns in AER IIa had negative average rates of rainfall change indicating that received rainfall in the region was on the decrease (-1.09mm/year) over the period 1910 to 2009. On the other hand average annual temperatures had increased (0.023ºC/year) for AER II during the period 1945 to 2009.

5.3 Adaptation Measures and Coping Strategies by Small-scale Farmers in Choma to Climate Variability

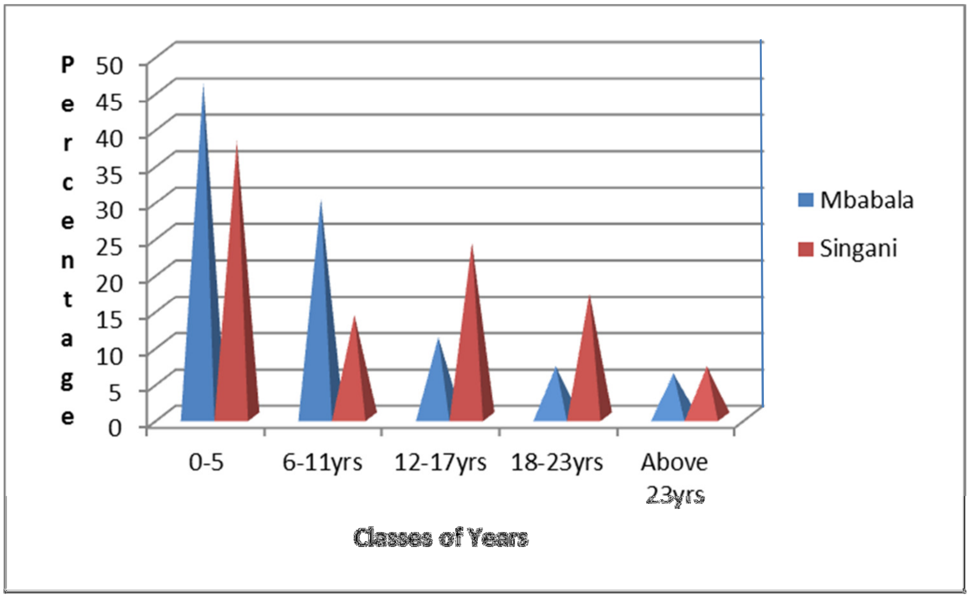
This section presents the adaptation measures employed by small-scale farmers to impacts of climate variability as well as short term coping strategies to survive the impacts. A total of 112 households were sampled with household heads being targeted. The analysis starts with demographic characteristics of the sample, crop types cultivated, maize variety preference and reasons for such preferences. It will also include adaptation measures and coping strategies by the farmers in the study area.

5.3.1 Demographic Characteristics of the Sample Sites

Mbabala and Singani wards were the study sites in Choma. Of the 83 households interviewed in Mbabala, 46 (55%) were male headed while 37 (45%) were female headed. This implied a near balance in the sample as the two figures are close. On the other hand, the gender balance in Singani was tilted towards male headed household who enjoyed a 72% (21 male headed households) lead while 8 (28%) female headed households were interviewed. Most of the respondents (46% for Mbabala and 38% for Singani) have been farming for not more than 5 years with only a few having done it for more than 23 years (6% for Mbabala and 7% for Singani) (Figure 13).

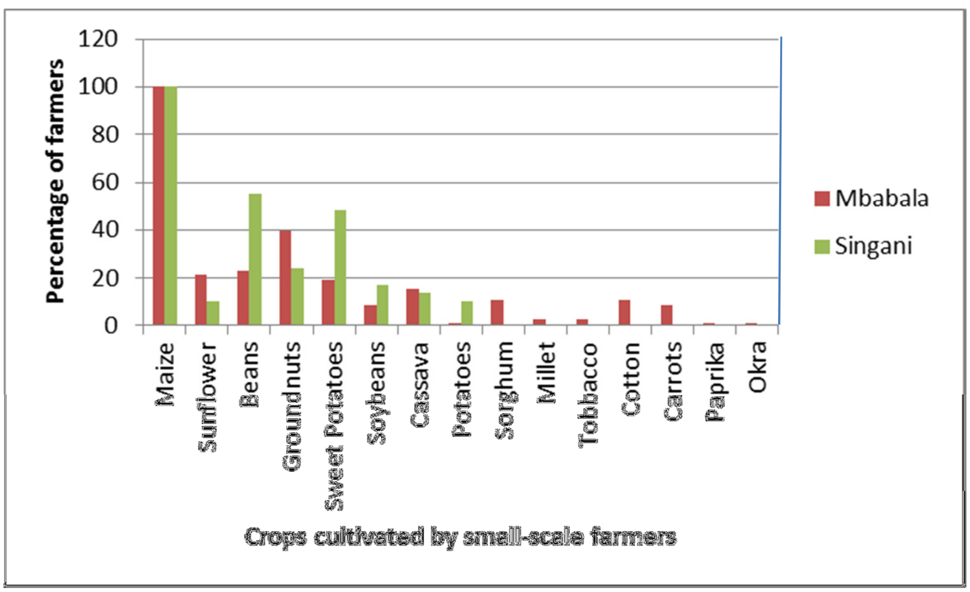
5.3.2 Crops Cultivated by Small-scale Farmers in the Study Sites

Like in many parts of Zambia, maize is the most commonly cultivated crop among the small-scale farmers. All the 112 respondents sampled in Mbabala and Singani cultivated at least one variety of maize, making it the staple food in the area. Other crops cultivated in Mbabala included Sunflower, Beans, Groundnuts, Sweet Potatoes, Soya Beans, Cotton, Cassava, Sorghum, Millet, Tobacco, potatoes, Carrots, Paprika and Okra. On the other hand, the commonly cultivated crops in Singani with the exception of maize included Beans, Potatoes, Sweet Potatoes, and Groundnuts, Cassava, Sunflower and Soya Beans (Figure 14).



Source: Field Data

Figure 13: Number of Years Spent as a Farmer in the Study Site



Source: Field Data

Figure 14: Crops Cultivated by Small-scale farmers in Mbabala and Singani

Maize was the most preferred crop for cultivation in both Mbabala and Singani as it was cultivated by all the small-scale farmers in the study sites. All the farmers cultivated at least more than one crop each season. Most of these farmers also had gardens where they cultivate vegetables even during the dry season.

5.3.3 Adaptation Measures by small-scale Farmers in the Study Sites

Most of the farmers in the study sites had problems understanding the question of adaptation measures as they could easily explain coping strategies when asked rather than adaptation measures. Hence the researcher had to try and elaborate for the farmers to understand and at times had to pick the adaptation measures from the combination of adaptation measures and coping strategies given by the farmers. In most instances a farmers would use more than one adaptation measure rather than restrict themselves to one. Hence these adaptation measures were not mutually exclusive and this explains why the percentage of farmers using these adaptation measures is more than 100% in Table 14. All the 112 interviewed farmers said they have been using early maturing maize varieties either provided by the cooperatives in their area or bought from shops in Choma. In Singani, 76% said they have been using drought resistant crop varieties as compared to the 81% in Mbabala who had used the same measure to combat variability (Table 14). Farmers used more than one adaptation measure hence the percentage does not add up 100%.

Table 14: Percentage of small-scale farmers in Singani and Mbabala using particular adaptation measures

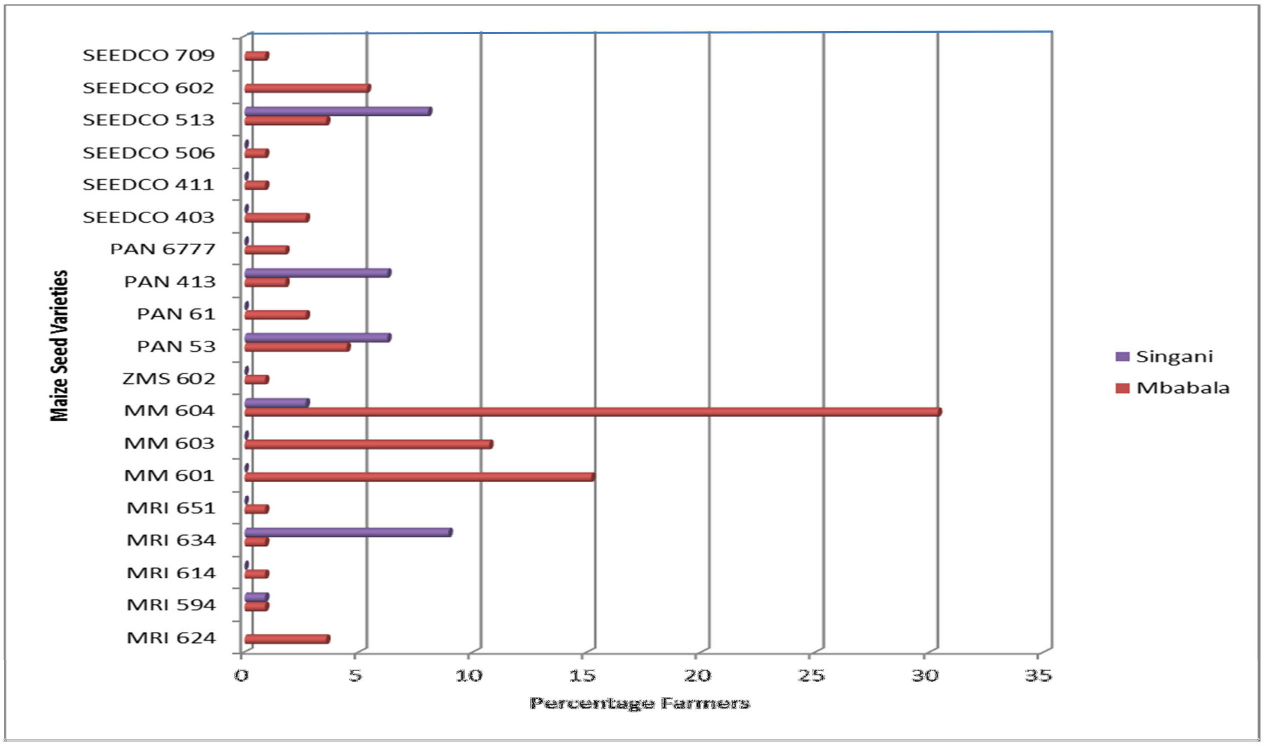
Adaptation Measure	**Singani (%)**	**Mbabala (%)**
Use of early maturing maize varieties	100	100
Use of drought resistant crops	76	81
Conservation farming (use of basins)	28	17
Use of substitute/complementary crops e.g. Cassava, Sorghum, Beans	55	23
Just grow whatever is available	10	2.4

Conservation farming was being practiced by 28% of the farmers in Singani and 17% of the farmers in Mbabala as it was being promoted by CFU field agents in the study sites.

Since all the farmers in the study site cultivated maize and most of their adaptation measures centered on maize growing, the study investigated the cultivated maize varieties and determined reasons for preference of certain varieties.

5.3.4 Maize Varieties Cultivated in the Study Sites

Most small-scale farmers in Mbabala (30%) planted MM 604 in the 2010/11 agriculture season with MM 601 (15%) and MM 603 (10%) also being planted by a number of farmers. On the other hand, while MM 604 was the most planted variety in Mbabala, Singani farmers mostly planted MRI 634 (9%) while 8 % planted SC 513 (Figure 15).



Source: Field Data

Figure 15: Maize Varieties Grown in Mbabala and Singani

Seed variety distribution for planting among farmers in Singani was more evenly distributed in Singani than in Mbabala. Farmers in Singani preferred a wider range of varieties compared to those in Mbabala where MM 604 was largely preferred.

5.3.5 Preferred Maize Varieties by Small-scale Farmers in Mbabala and Singani

Despite their limited choice regarding maize varieties for planting, small-scale farmers in the study sites had particular maize varieties which they preferred for planting (Figure 16).

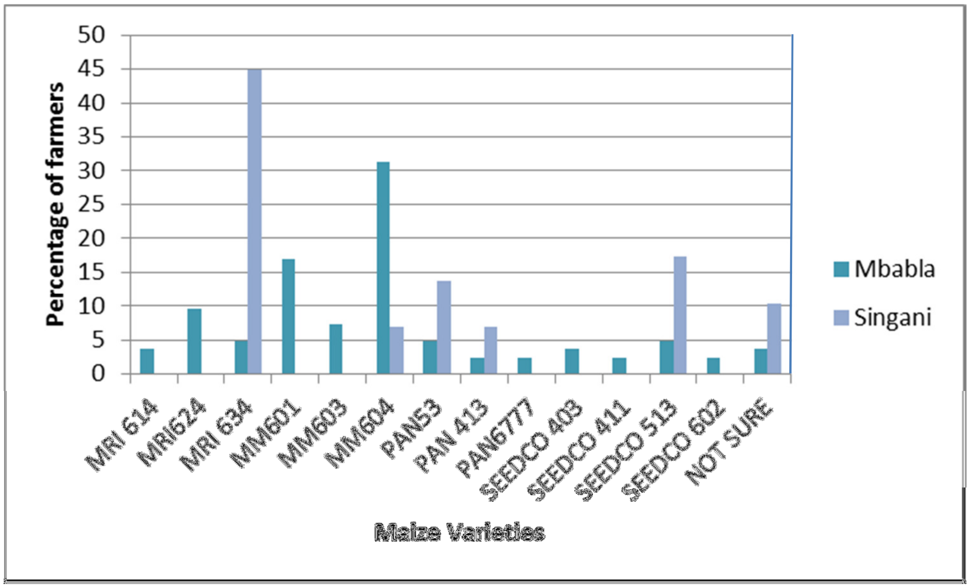


*Figure 16: Preferred Maize Varieties in Mbabala and Singani (S*ource: Field Data*)*

Most of the farmers in Mbabala preferred to cultivate MM 604 (31%) while the majority in Singani (45%) planted MRI 634 (Figure 16). Table 15 gives the reasons given by farmers for their preferred maize varieties.

Table 15: Reasons for Preferred Maize Varieties by Small-scale Farmers in Singani and Mbabala

Preferred Maize Variety	**Reasons for Preference**
MRI 634	➢ It is drought tolerant ➢ It's a high yielder because of its ability to bear 2 cobs ➢ It is cheaper
SC 513	➢ It is drought tolerant ➢ Requires minimal fertilizer ➢ It's a high yielder ➢ It can stay for a long time without rotting after being harvested.

Preferred Maize Variety	Reasons for Preference
MM 604 MM 603	➢ It requires less fertilizer ➢ Friends say it is a high yielder (first time planting it) ➢ Not easily affected by droughts ➢ It is what we were given by the cooperative so it has to be good ➢ MM 604 weighs more than the other varieties hence fetches a bigger profit when sold to the Food Reserve Agency (FRA)
PAN 413 PAN 53	➢ It has big cobs and is early maturing ➢ It was cheaper on the market ➢ It does not require a lot of fertilizer

Farmers in the study area who preferred MRI 634, SC 513, MM 604 and MM603 (Figure 17) claimed the varieties were relatively tolerant to droughts and even though they required minimal fertilizer application they were high yielders. For the farmers (3.5%) who preferred PAN 53 and the (2%) who preferred PAN 413, their reasons for preference were that the variety had big cobs, was cheaper on the market and did not require a lot of fertilizer.

5.3.6 Coping Strategies by Small-scale Farmers in Mbabala and Singani to Impacts of Extreme Climate Variability

Droughts, and in recent years, floods have been a common occurrence in Mbabala and Singani. The 2007/08 floods had severe effects on the residents of both Mbabala and Singani. These floods swept the crops in the farmers' fields and the hunger that resulted was only abated by a supply of relief food to these areas. Occurrence of such impacts of climate change has resulted in farmers devising survival strategies during such times of crop loss. The following are the coping strategies embarked by farmers in Mbabala and Singani to ensure survival during times of droughts and/or floods.

- Some farmers have been cultivating crops such as Okra, Cassava and Beans which are not adversely affected by droughts and floods. These crops have been surviving droughts and/or floods and the farmer would then sell these to buy mealie meal if his/her maize did not do well.

- Almost all the farmers interviewed owned a garden near the stream where they grew maize and vegetables like tomatoes, cabbage, rape and pumpkin leaves for sale. While these gardens are functional whether there is a drought or flood in a particular season, they take on special meaning when droughts and floods strike as they now act as the means of survival for farmers who may have lost their crops in the field. Hence these gardens have been helping farmers to cope during the times of droughts and floods.

- Some farmers have diversified their income generating ventures to include charcoal burning as a coping strategy during the times of droughts and floods. However, charcoal burning in Mbabala and Singani is illegal unless with permission from the village headman. Unsupervised cutting down of trees attracts a penalty from the village headman.

- Cultivation of sugarcane by some farmers has helped them to cope during the times of droughts and floods and is sold to raise money for mealie meal.

- Some farmers engage in casual labour to help them cope in times of droughts and floods. These farmers could either work for food from fellow farmers who at least managed to harvest or they could move to Choma town to look for work. When paid these farmers would buy mealie meal for food.

- Some farmers would go and buy fish from Mamba which would later be sold in Choma to help them cope. These farmers would first sell an animal (goat or a cow) to get money to buy fish from Mamba. Other farmers are also fishermen who tend to concentrate on fishing in times of droughts and floods. The fish would later be sold in Choma to buy maize for grinding or mealie meal. This method of income diversification represents a livelihood circuit.

It is noteworthy that most farmers are also engaged in other income generating activities. In line with the concept of ‘diversification’, these farmers have diversified their livelihood to include such activities like fishing, making mats, charcoal burning etc. It is these extra activities which support these farmers during the dry season or during times of droughts and floods.

5.4 Recommended Maize Varieties for AER II by Seed Breeders

In line with the development of drought tolerant and early maturing crop varieties, the Government of Zambia had been encouraging small-scale farmers to be planting agro-ecological specific maize varieties suitable to the meteorological conditions in their region. Farmers in drought prone areas of AER I and II were advised to plant maize varieties with high yield potential, and which had been found to have high water use efficiencies and were early maturing. Four companies involved in maize breeding in Zambia were sampled to determine the climatic characteristics of their recommended maize varieties for each of the AERs with particular emphasis on AER II. These companies included ZAMSEED, SEEDCO, MRI Seed and PANNAR. AER II is generally referred to as the medium rainfall region with a growing period of 120 to 140 days. Hence if a variety was to be recommended for this region it had to be able to mature within this period. It was recommended that farmers plant the variety with the highest yield potential. For this region a variety with an average yield potential of 8 t/ha was good enough for cultivation.

5.4.1 ZAMSEED

ZAMSEED had been recommending 11 varieties for cultivation in AER II with a range of maturity days from 105 to 135. ZMS 616 had the highest yield potential of 10-12 t/ha while ZMS 606 and 602 had a yield potential of 8-10 t/ha. The other varieties had a yield potential between 6 t/ha-8 t/ha. Table 16 showed the maize seed varieties recommended for AER II by ZAMSEED Company.

Table 16: Recommended maize varieties by ZAMSEED Company

Maize Variety	Maturity Days	Moisture Requirement (mm)	Year Produced	Recommended Region for Production	Yield (t/ha)	Classification of Variety/ Maturity Group
ZMS 402	105-110	800-1000	2006	I,II	6-8	Early Maturing
GV 412	105-110	800-1000	1998	I,II	6-7	Early Maturing
MM 441	110-115	800-1000	1992	I,II	6-7	Early Maturing
MM 502	120-125	800-1000	1984	II,III	8-9	Medium Maturing
ZMS 510	120-125	800-1000	-	I,II	8-9	Medium Maturing
ZMS 528	120-125	800-1000	-	I,II	8-9	Medium Maturing
ZMS 602	130-135	800-1000	-	II,III	8-10	Medium Maturing
MM 603	125-130	800-1000	1984	II,III	6-8	Medium Maturing
MM 604	125-130	800-1000	1984	II,III	6-8	Medium Maturing
ZMS 606	125-130	800-1000	2006	II,III	8-10	Medium Maturing

Maize Variety	Maturity Days	Moisture Requirement (mm)	Year Produced	Recommended Region for Production	Yield (t/ha)	Classification of Variety/ Maturity Group
ZMS 616	125-130	800-1000	-	I,II	10-12	Medium Maturing

Source: ZAMSEED Company. A dash (-) indicates lack of available data

While all the varieties in Table 16 could generally do well in AER II with good management, it was recommended that farmers plant the variety with the highest yield potential. Hence ZMS 616 would be the ideal choice considering not only its yield potential but also its adaptability, stability, disease resistance, and drought tolerance. ZMS 606 would be suitable for cultivation especially in cases where ZMS 616 is not available.

5.4.2 SEEDCO

SEEDCO had been promoting 11 varieties for AER II and of these SC 637 had the highest yield potential (6-13t/ha) while SC 403 had the lowest yield potential (1-5t/ha). In spite of having a large potential yield SC 637 would not be a good choice for AER II as its maturity days (148) was nearly the upper threshold for the actual maturity days for AER II (150 days). The company had also been promoting three yellow maize varieties (SC 506, 608 and 602) of which only SC 506 would be good for AER II since its maturity days were below the maximum for AER II. Table 17 showed the recommended maize varieties for AER II by SEEDCO Company.

Table 17: Recommended maize varieties by SEEDCO Company

Maize Variety	Maturity Days	Moisture Requirement (mm)	Year Produced	Recommended Region for Production	Yield t/ha	Classification of Variety/ Maturity Group
SC 403	131	800-1000	1999	I,II	1-5	Very Early Maturing
SC 411	132	800-1000		I,II	4-8	Very Early Maturing
SC 513	137	800-1000	1999	I,II	4-8	Early Maturing
*SC 506	132	800-1000	2004	I,II	1-6	Early Maturing
SC 525	134	800-1000	2006	I,II	5-10	Early Maturing
*SC 608	148	800-1000	1998	I,II	5-14	Medium Maturing
SC 621	148	800-1000	1999	II,III	3-8	Medium Maturing
SC 627	144	800-1000	1999	II,III	5-10	Medium Maturing
*SC 602	148	800-1000	2001	II,III	5-13	Medium Maturing
SC 633	140	800-1000	2002	II,III	6-12	Medium Maturing
SC 637	148	800-1000	2004	II,III	6-13	Medium Maturing

Source: SEEDCO. A blank indicates lack of available data *Yellow Maize

With a growing period of 120 to 150 days in AER II, early planting was strongly advised for medium SEEDCO varieties as soon as the onset of rains. Taking into account the maturity days and potential yields for most SEEDCO varieties, SC 525 would be the most suitable for planting in AER II among the SEEDCO varieties.

5.4.3 PANNAR

PANNAR SEED had been promoting eight varieties of which only PAN 6966 is yellow maize. This variety was a high yielder with a potential yield of 9 t/ha-12 t/ha. PAN 53, 6243 and 6823 had potential yields of 8 t/ha-10 t/ha while the other varieties had between 7 and 9 t/ha potential yield. All the recommended PANNAR varieties had their maturity days below 150 days for AER II (Table 18).

Table 18: Recommended maize varieties by PANNAR Seed Company

Maize Variety	Maturity Days	Moisture Requirement (mm)	Year Produced	Recommended Region for Production	Yield (t/ha)	Classification of Variety/ Maturity Group
PAN 4M-19	100-110	750-1000	2005	I,II		Early Maturing
PAN 413	110-115	750-1000	2006	I,II		Early Maturing
PAN 6823	120-130	750-1000	2001	I,II	8-10	Medium Maturing
PAN 67	120-130	750-1000	2003	II,III	7-9	Medium Maturing
*PAN 6966	125-140	750-1000	2004	II,III	9-12	Medium Maturing
PAN 53	125-135	750-1000	2006	II,III	8-10	Medium Maturing
PAN 6243	130-140	750-1000	1997	II,III	8-10	Medium to Late
PAN 14	130-145	750-1000	2005	II,III	7-9	Medium to Late

Source: PANNAR Seed *Yellow Maize

With the exception of PAN 14 all the other varieties can be cultivated in AER II since their growing period was within the 120-150 days for AER II. However, for medium maturing varieties early planting is strongly advised. PAN 6966 would be a good variety for planting if one prefers yellow varieties while PAN 6823 would be good for those who prefer white maize.

5.4.4 MRI Seed

MRI Seed had been promoting 11 maize varieties of which only MRI 651 was a yellow variety. All the varieties mature in fewer days than the growing period of 150 days for AER II. The 600 and 700 series are not encouraged for cultivation in low rainfall areas of AER II. However, they can be cultivated in high rainfall areas. This means that all the 500 series and the 400 series recommended by MRI can be cultivated in all areas of AER II. All the 500 series had a potential yield of 10t/ha while MRI 455 had a potential yield of 8 t/ha (Table 19).

Table 19: Recommended maize varieties by MRI Seed Company

Maize Variety	Maturity Days	Moisture Requirement (mm)	Year Produced	Recommended Region for Production	Yield (t/ha)	Classification of Variety/ Maturity Group
MRI 455	90-110	750-1000	1998	I,II	8	Early Maturing
MRI 514	90-110	750-1000	2001	I,II	10	Early Maturing
MRI 614	110-135	750-1000	1998	II,III	10	Medium Maturing
MRI 594	110-135	750-1000	2000	II,III	10	Medium Maturing
MRI 634	110-135	750-1000	2000	II,III	10	Medium Maturing
MRI 624	110-135	750-1000	2001	II,III	11	Medium Maturing
*MRI 651	110-135	750-1000	2002	II,III	12	Medium Maturing
MRI 534	110-135	750-1000	2002	II,III	10	Medium Maturing
MRI 694	110-135	750-1000	2004	II,III	13	Medium Maturing
MRI 644	110-135	750-1000	2005	II,III	13	Medium Maturing
MRI 734	110-135	750-1000	1998	II,III	11	Medium Maturing

Source: MRI Seed *Yellow Maize

All the recommended MRI varieties can be planted in AER II. However, MRI 514 was more adaptable to the climatic conditions of AER II and was drought tolerant (Table 22) making it the best variety for cultivation in AER II than the other varieties recommended by MRI Seed.

In retrospect, the presented results showed a variation in the trends of the rainfall and temperature CVs and the rainfall graphs. It further showed the maize varieties recommended by the seed breeder. However, in spite of the fact that all the maize varieties recommended by seed breeders for AER II could be grown in the region, it does not mean that all of them could produce the best results. Hence in the discussion chapter, the best varieties for planting considering the yield potential and climatic conditions in the region were discussed.

CHAPTER SIX

DISCUSSION

6.1 Introduction

The chapter discusses rainfall and temperature variations in AER II from 1910 to 2009 and 1945 to 2009, respectively as illustrated from the CVs. It further discussed the recommended maize varieties for AER II by the seed breeders and the coping strategies and adaptation measures instituted by small-scale farmers in the face of climate variability. The chapter further discusses the implications of extreme climate variability on small-scale farmers in AER II.

6.2 Climatic Variations in AER II

The rainfall and temperature variability calculated using the Coefficient of Variability and the ANOVA are discussed under this section for the entire study area-AER II.

6.2.1 Rainfall Variations in AER II, 1910-2009

The analysis of rainfall variations in AER II showed that Northern Western Province (Mongu) experienced the lowest rainfall variation while the southern part of the same province experienced the highest variability since the 1950s with Sesheke and Senanga showing increased variations. Rainfall trends in Sesheke were characterized by moderate variations before 1950 with increased seasonal variability after 1950 marked by large CVs (37.5 to 52.2) which are the effects of single unusually wet years. Kaoma on the other hand experienced relatively stable variations in the long-term, although seasonal variations were evident. Eastern Province (Chipata) experienced low to moderate rainfall variability while Central Province (Mumbwa and Kabwe) had increasing rainfall variability. Southern Province (Choma) experienced increased variability after 1950 with a tendency towards dryness after the 1970 culminating into a drought in the 1990s. The general rainfall trend for all the towns in the region has been a decrease in rainfall received especially after the 1980s. Only Chipata recording increased overall rainfall over the period 1910 to 2009. But was this variation observed from the CVs significant?

The ANOVA, which was used to determine the significance of the observed rainfall variability, gave an F-ratio of 2.94 and a P-value of 0.036 as the result for the analysis. This meant that the null hypothesis (Section 1.5) was rejected since the probability of having no significant variations in the rainfall data set was 0.036 which was not significant. Hence, there were significant variations in the amount of rainfall received in AER II over the last century (F=2.94, P<0.036) implying that the rainfall received had significantly changed over the course of the century. The average annual rate of change for rainfall in AER II over the past century had ranged from -3.01mm (Kalabo) to 0.79mm (Chipata). The average annual rate of decrease for the region was found to be -1.09mm implying that AER II had experienced decreased rainfall at an annual rate of 1.09mm over the past century. All the towns in the region with the exception of Chipata experienced negative rates of rainfall change. Chipata, the wettest town in the region, experienced a positive rate of rainfall increase (0.79mm). Hence AER II had been experiencing a tendency towards dryness.

The analysis of rainfall variability indicated that AER II of Zambia had been experiencing significant rainfall decrease at a rate of -1.09mm per year. This shift in rainfall patterns is expected to produce a corresponding shift in crop growing zones. Since agriculture in Zambia is largely rain fed it is expected that the agriculture pattern will shift northwards too. Furthermore, it has been observed that the change in rainfall patterns in Zambia has been such that AER I had been expanding northwards to include regions previously experiencing conditions for AER II, while AER II has also been expanding northwards to include areas previously experiencing conditions for AER III (Shitumbanuma, 2008). The results also showed that while there had been a continuous variability in rainfall received in AER II, this variation has increased since the 1980s. This has been demonstrated by deviations from the long-term mean (normal for the period 1910 to 2009) after 1980 onwards. This indicated a change in rainfall patterns received in AER II.

Zambia's experienced decreased rainfall activity in the 1980s and 1990s has been related to the observed sea surface temperature increase (Strong 1989). The country experienced droughts in the years 1912, 1913 1916, 1924,1933,1946,1949,1954,1964,1987, 1992, 1994,1995,1996,1997, 1998, and 1999. The severest one-year drought was the 1916 in Southern Zambia with a 59% departure from the normal rainfall centered at Livingstone. However, this drought did not have as much adverse impacts as did the 1992 drought which impacted 88% of the country resulting in only 4.5 million bags of maize being harvested instead of the expected 12 million (Banda et. al., 1997). The adverse impacts in 1992 were more than those experienced in 1916 because of the increased population and unsustainable methods of agriculture occasioned by a rapid expansion of cultivated areas (Lekprichakul 2008) in the 1992 season as compared to the 1916 season. The small population in 1916 was not as destructive to the environment as was the 1992 population. Furthermore, the changed social economic status and environmental factors between 1916 and 1992 amplified the impacts of the 1992 drought. Because of this some believe that the 1992 drought is the worst in recent history and not the 1916 one (Tiffen and Mulele, 1994).

6.2.2 Temperature Variations in AER II, 1945-2009

The study of temperature variations in AER II showed that northern Western Province (Mongu) experienced the lowest temperature variation while the southern part of the province experienced the highest temperature variability especially since the 1980s with Sesheke showing the highest variability. With the exception of Mongu and Kaoma, all the sampled towns in AER II experienced increased variations especially since the 1960s with the increase becoming abrupt after the 1980s. Kaoma was the only town in the region which experienced decreased variation during the period 1945 to 2009. This implied that northern Western Province experienced the lowest temperature variability while Eastern Province (Chipata) and Central Province (Kabwe) had been experiencing large variations in temperatures since the 1980s. Southern Province (Choma) had been experiencing relatively stable temperatures since the 1970s with moderate CVs ranging from 1.7 to 2.4.

The ANOVA used to determine the significance of the experienced temperature gave an F-ratio of 15.17 and a P-value of 0.001. This meant that the null hypothesis (section 1.5) was rejected since the probability of having no significant variations in the temperature data set was 0.001 which was almost zero. Hence, the alternative hypothesis was adopted and it was concluded that there were significant variations in temperature in the different parts of AER II over the last century. The annual rate of temperature change in the region ranged from 0.005ºC/year (Senanga) to 0.04ºC/year (Monze). The average annual rate of temperature increase in AER II was found to be 0.023ºC with Senanga in southern Western Province experiencing the lowest rate of increase (0.005ºC/year) while Monze in Southern Province experienced the highest temperature rate of increase (0.04ºC/year). The positive temperature rate of increase for all towns in the region implied that AER II had been experiencing an increase in temperature over the past century. The region had a tendency towards hotness.

The study showed that Senanga in the Western Province of Zambia had the highest temperatures in the region with a mean of 23.09ºC (StDev=0.611) with Mongu in same Province recording the second highest temperatures averaging 22.84ºC (StDev=0.605). Generally, the Western and Eastern provinces had the highest temperatures in AER II with Choma in Southern Province having the lowest temperatures with a mean of 19.54ºC (StDev=0.661). Lusaka and Central provinces received moderate temperatures ranging from 20.64ºC to 21.85ºC. This could have been due to their being in moderate temperature zones as compared to the other towns in AER II.

6.3 Recommended Maize Varieties for AER II by Seed Breeders

The recommended maize varieties (Tables 16-19) by the four seed breeding companies, namely; ZAMSEED, SEEDCO, PANNAR and MRI Seed were analyzed based on the yield potential of particular varieties and adaptability to particular climatic conditions. It is worth noting that AER II (generally referred to as the medium rainfall region) has a growing period of 120 to 150 days (GRZ, 2002). Hence if a seed variety is to be recommended for planting it has to mature within this period.

While all the varieties recommended by ZAMSEED in Table 16 could generally do well in the region with good management, it was recommended that farmers plant the variety with the highest yield potential. ZMS 616 was the best variety to cultivate as it had the highest yield potential (10-12 t/ha). Furthermore, its adaptability to a range of climates and disease resistance was excellent while its tolerance to droughts was very good (Table 20). The variety was also flexible as it may tend to behave like an early maturing variety if less than enough rainfall was received for that particular season. In cases where ZMS 616 was unavailable, ZMS 606 and ZMS 602 both of which had a yield potential of 8-10 t/ha would be a fitting bargain for small scale farmers.

Of the two ‘very early maturing’ varieties recommended for AER I and II by SEEDCO (Table 17), SC 403 was more resistant to a wide range of diseases. SC 411 is a higher yielding variety but should only be planted in areas where Northern Corn Leaf Spot (NCLS) and Common Rust diseases are not a threat as it is very susceptible to these diseases (Table 20). However, SC 525 was a better choice not only in areas susceptible to these diseases but also in cases where high yields were expected. Furthermore, this variety is more adaptable and stable and is highly recommended in marginal areas where synchronization is important in case one wants to use it as a complement to SC 513.

With the exception of PAN 14, all the varieties recommended by PANNAR in Table 18 could do well with good management in AER II. However, PAN 14 borders on late maturing and may require both early planting and irrigation if it is to do well. Such management is usually beyond the financial capacity of small-scale farmers. PAN 6966 is a high yielding variety and would be an excellent choice for farmers who would like to cultivate yellow maize. However, the preference for most farmers in Zambia is the white variety (JAICAF, 2008) in which case PAN 6823 and PAN 6243 would fill this preference. In this case the farmer should ensure to plant early enough as the growing period for these varieties tend to border on the growing period for AER II. Furthermore good management is strongly advised if the yield for these varieties is to come close to their yield potential. In cases were these varieties are not easily available as is the case in Choma, PAN 413 would be a good replacement.

The high yielding varieties for MRI Seed (MRI 624, 634, 644, 651, 694 and 734) in Table 19 would tend to be the best options for cultivation by small-scale farmers. However, they are not recommended for small-scale farmers because they require very good management if they are to do well, management which may be beyond the financial muscle of most small-scale farmers. This is because most of these varieties are single cross pure breeds. They require a good supply of fertilizer which should be top-dressed twice. Therefore, considering the conditions in AER II, MRI 514 would be the most recommended variety. This is because it is not only early maturing but also highly adaptable and flexible. It is considered to be both an early and medium maturing variety because it adapts to the nature of the rainfall in a particular season. If there is low rainfall it behaves like an early maturing variety while in case of high rainfall it is a medium maturing variety. An analysis of the maize varieties discussed above using themes isolated six varieties suitable for cultivation in AER II. These varieties are presented in Table 20 below.

Table 20: Characteristics of Recommended Maize Varieties for AER II

Maize Variety	**Maturity Days**	**Adaptability**	**Disease Resistance**			**Drought Tolerance**	**Potential Yield (t/ha)**	**Climatic Conditions**	
			Grey Leaf Spot	**Leaf Blight**	**Cob Rot**			**Rainfall (mm)**	**Mean Temperature (◦C)**
ZMS 606	125-130	VG	VG	VG	EX	VG	8-10	800-1000	18-24
ZMS 616	125-130	EX	EX	EX	EX	VG	10-12	800-1000	18-24
PAN 6966	125-140	EX	G	VG	VG	VG	9-12	750-1000	18-24
PAN 6823	120-130	EX	VG	EX	EX	G	8-10	750-1000	18-24
MRI 514	125-130	VG	VG	VG	VG	EX	10	750-1000	18-24
SC 525	130-135	VG	G	VG	G	VG	5-10	800-1000	18-24

Key: G=Good, VG=Very Good, EX= Excellent

While ZAMSEED's ZMS 616, ZMS 606, SEEDCO's SC 525, PANNAR's PAN 6966 or PAN 6823 and MRI Seed's MRI 514 can do well in AER II, the characteristics of the recommended maize varieties show that ZMS 616 is the best variety for planting in AER II. However, most farmers in Mbabala preferred growing MM 604 which has a yield potential of 6-8 ton/ha. This could be because of a number of factors. Firstly, lack of adequate sensitization by seed breeders could have led to farmers' lack of understanding as to the characteristics of the varieties being planted. It could also be due to the unavailability of some maize varieties in the region. Most agriculture shops in Choma at the time of data collection were well stocked with seed varieties like MM 601, MM603, SC 513, R215, PAN 413 and PAN 53. However, the researcher could not see the ZMS 616 or 606 indicating that the seed variety may not have been common in the region. Even when most farmers were asked about this variety, they had never used it before, either because their cooperative has not been distributing it or they have never seen any one plant it and so they were skeptical about it.

SEEDCO Company has been promoting two 'very early' maturing maize varieties for the season 2010/2011; SC 411 and SC 403 which take about 132 and 131 days respectively, to mature. This is in contrast to the maturity classes classified by ZASTA (2008) as presented in Table 2.

If the classes in Table 2 were to be followed, the 'very early' maize varieties by SEEDCO would fall in the medium maturing variety and the company would have no early maturing variety. In the same way, SEEDCO's medium maturing varieties even go up to 148 days when the threshold is at 135 days for medium maturing varieties. This highlights the need to provide checks and balances to the seed breeding industry so as to protect unsuspecting farmers from buying seed which may not be suitable for their regions.

The early maturing varieties for PANNAR take about 120-130 days while the early maturing varieties for ZAMSEED and MRI takes about 105 to 115 days and 90 to 110 days, respectively. In fact, the earliest variety ever produced in Zambia is Pool 16 by ZAMSEED which takes about 95 to 100 days to mature. However, the company has not been promoting it of late as it is open pollinated and can easily be recycled by farmers yet still be able to maintain its original traits. This is not good for a company which is driven by commercial interests hence the seed breeding industries have been concentrating on producing hybrid seed varieties as opposed to open pollinated ones. This helps to boost the business as these hybrid seeds do not maintain their original traits if they are recycled and this forces farmers to buy these seeds every year.

The difference in maturity classes by the different companies raises the need to establish cross-cutting maturity classes which should be adhered to by all seed breeding companies. This also establishes the need to enforce the day limits for the different maturity classes with appropriate penalty given to defaulters who may confuse ignorant small-scale farmers.

6.4 Adaptation Measures and Coping Strategies by Small-Scale Farmers in AER II

Of the two study sites Mbabala had more female headed households during the study period compared to Singani. One reason for this could be due to many farmers in Mbabala ward also being workers in Tobacco farms owned by commercial farmers. When these farmers were given leave from work, they went to their villages such as Mapanza, Siachitema, Muchila, Chitongo etc. to do farming during the rainy season while their wives remained heading the household during the husband's absence. However, regardless of the respondents' gender, all the farmers cultivated maize and so most of their adaptation measures centered on maize growing.

However, a farmer's choice of which maize varieties to plant during the rainy season was limited by not only financial constraints but also the availability or lack of some maize varieties on the market in a particular growing season. The formation of cooperatives and the Fertilizer Support Programme (FSP)-currently Farmers Input Support Programme (FISP) - helped to provide seeds and fertilizer to small-scale farmers. Different maize seed varieties and fertilizer were given to farmers through cooperative formed by the same farmers in their respective communities. However, this arrangement had further reduced the farmers' choice regarding preferred seed varieties for planting. This was because farmers were not consulted as to the variety they would want to plant before these seeds were given to them. Hence they ended up planting what was available through the cooperatives and not necessarily what they preferred. Besides this, not all farmers were attached to cooperatives and not all of them were recognized under FSP. These farmers bought the available seeds in shops and these seed varieties tend to change depending on which varieties were being promoted for that particular season. Even farmers attached to cooperatives and under FISP tend to buy seeds from shops as the seeds and fertilizer given to them was usually not enough for the cultivated land, hence they bought these inputs to supplement the seeds acquired through their cooperatives. Furthermore, as was the case, farmers usually planted more than one maize variety per season just as they grew more than one crop.

With the research in plant improvement and breeding receiving continuous support, maize varieties on the market keep on changing as seed breeders continue improving the already existing hybrid varieties. The general understanding by most interviewed farmers was that as long as a variety was new, it had to be better than the varieties bred before. However, sometimes they find unfavorable traits even in the new varieties, the most common being that a variety may be easily attacked by pests when ready for harvest. Hence a farmer may incur severe losses if he/she delays in harvesting the crop. A variety may equally be susceptible to pests and fail to last long after harvest. Therefore, there is need to sensitize farmers on chemical applications after harvest when the maize is in storage.

Most farmers in the study sites attested to the frequency of droughts and/or floods in the region. This showed a serious need to devise coping strategies and adaptation measures especially by small-scale farmers since they are the most affected by impacts of climate variability as their type of agriculture is rain fed.

6.4.1 Adaptation Measures

Adaptation involves adjustments to natural or human systems in response to experienced or future variability and extreme events or their effects. It is considered as a function of present or future vulnerabilities (GRZ, 2007; Kajoba, 2009). Since changes in the climate system are not easily reversible due to the complexity of the system and impracticality of change in people's livelihoods which are affecting the climate system, such variations in climatic conditions are here to stay, hence the need to adapt. Farmers in the study sites have been adapting to impacts of climate variability by switching to the use of hybrid maize seed varieties which are early maturing and drought resistant which are mostly provided through cooperatives. On the other hand, these farmers have been using supplementary and complementary crops such as Okra, Beans, Soya beans, Sorghum, Millet and Cassava. During the periods when maize which is a seasonal crop, does not do well, crops like Cassava-a perennial crop-tends to provide the necessary sustenance. Sorghum and Millet are used in a similar sense. On the other hand, Beans, Soya beans, Okra are grown simultaneously with maize hence supplementing the maize yields. However, some farmers said they grow whatever was available and did not pay attention to whether they were adapting or not. Even in such cases, these farmers admitted to also having been using supplementary and/or complementary crops. Furthermore, these adaptation measures were used in combinations and were not mutually exclusive as one farmer would use more than one adaptation measure. Some farmers had been practicing conservation agriculture (CA) being promoted by the Conservation Farming Unit (CFU). This usually involved the use of basin farming and planting leguminous crops like *Faidherbia albida* (Figure 17). The government through the Ministry of Agriculture in partnership with the Conservation Farming Unit, Conservation Agriculture Programme and the Royal Norwegian Government has been supporting CA in the study sites as a way to combating hazards of climate change by training and educating farmers on the benefits of CA over conventional agriculture. Demonstration plots have been set up to persuade small-scale farmers to adopt conservation farming. Promoters of

CA have further supported the planting of leguminous trees like *Faidherbia albida* (*Musangu*) as a way of improving soil fertility. The CA project has not been readily accepted by many farmers due to its labour intensive requirements and a reluctance for long-term investment on land which farmers may have tenure insecurities.

Figure 17: A fully-grown ***Faidherbia albida*** *tree in Choma. Note the maize growing under the tree.*

It is recognized that CA helps to conserve not only soil fertility and organic matter but it also conserves soil moisture making it one of the alternatives to sustainably adapting to impacts of climate variability such as droughts. Farmers who had been using this technology for a longer time reported relatively better harvests during the times of droughts. These observed adaptation measures in the study sites related to some of the proposed adaptation measures by GRZ (2007) to various climatic hazards (Table 21).

6.4.2 Coping Strategies

The strategies of dealing with the loss of crops are very similar among different communities (GRZ, 2007) in different areas of AER II. Section 5.3.5 presented the coping strategies practiced by farmers in the study sites. These involved crop diversification to include crops not easily affected by droughts and floods such as Sugarcane, Okra, Cassava and Beans. These supplementary and complementary crops provide the farmers with sustenance during the periods of droughts and floods when maize does not do well as the farmers could still sell these crops for income. On the other hand, the farmers also owned gardens near the stream and they not only did gardening during the dry seasons but these gardens also provided backup to maize during the periods when maize does not do well. These gardens which are usually used to cultivate vegetables sold for cash used for a variety of other things, takes on a different meaning during the seasons when maize does not do well as the cash is used to buy mealie meal. Charcoal production, casual labour, formation of livelihood circuits are also among the coping strategies which have enabled small-scale farmers to survive impacts of climate variability. GRZ (2007) confirms this when reporting that farmers cope by diversifying their sources of income and relying more heavily on alternative natural resources from forests and wetlands. The study findings corroborated GRZ (2007) findings on the main coping strategies used by different communities to combat the major impacts of climate variability (Table 22). The coping strategies do not differ much among different communities.

Table 21: Adaptation Measures by Small-Scale Farmers to Various Climatic Hazards in AER II

Climatic Hazard	Adaptation Measure
➢ Drought (seasonal and periodic), high temperatures, shortened growing season and delayed on-set of the rains	➢ Promotion of early maturing/drought resistant crops. ➢ Promotion of irrigation and efficient use of water resources and water harvesting ➢ Use of technologies for fertility improvement and moisture storage including conservation agriculture ➢ Strengthening of early warning systems and preparedness ➢ Promotion of improved crop management practices
➢ Floods and water logging	➢ Improve post-harvest storage and marketing of produce ➢ Strengthening of early warning systems and preparedness ➢ Develop sustainable and appropriate programmes for both crop and livestock in the face of climate change/variability

Adapted from GRZ (2007)

Table 22: Coping Strategies by Small Scale Farmers in AER II to Droughts, Floods and Extreme Heat

Drought	Floods	Extreme Heat
➢ Income diversification (Charcoal production, fishing, honey and beer production, selling grass and livestock, casual labour) to buy food ➢ Trading other commodities for food i.e. forming livelihood circuits ➢ Gathering and selling Non Timber Forest Products (NTFP) ➢ Selling less crops to keep more for household consumption ➢ Earlier crop planting ➢ Growing more drought resistant crops (e.g. cassava) ➢ Adopting conservation farming	➢ Income diversification (Charcoal, crafts, fishing, mats and beer production, selling grass and livestock, casual labour) to buy food ➢ Trading other commodities for food i.e. forming livelihood circuits ➢ Gathering and selling NTFP ➢ Early evacuation when water levels increase	➢ Income diversification (Charcoal, crafts, fishing, mats and beer production, selling grass and livestock, casual labour) to buy food ➢ Trading other commodities for food i.e. forming livelihood circuits ➢ Gathering and selling NTFP

Adapted from GRZ (2007)

The major coping strategy embarked on by farmers in cases of crop failure has been income diversification through such activities like charcoal production and selling, brewing beer for sale, fishing, selling crafts, livestock and even own labour. In most communities, coping strategies involved establishment of livelihood circuits. For example, in case of poor produce in the study site, farmers in Singani or Mbabala tends to sell some of their livestock to traders in order to raise cash with which to buy fish from fishermen from Lake Kariba or Kafue River. Then the farmer would sell the fish to raise money to buy maize from grain farmers whose crop did well that season. Alternatively, a farmer may choose to barter his fish directly with maize from fellow farmers. The farmer then returns with grain and grinds it to obtain mealie meal (or he would just buy mealie meal) for food, and the cycle begins. Usually this circuit is over different towns since fishing camps, livestock traders and maize farmers could be located in different towns and the small-scale farmer has to move across these towns to complete his/her cycle.

6.5 Implications of Climate Variability on Maize Growing by Small-Scale Farmers in AER II

Climate variability can manifest itself through droughts, floods and extreme temperatures. As a part of government response to these climatic hazards, the Ministry of Tourism, Environment and Natural resources (MTENR) with support from cooperating partners had established a Climate Change Facilitation Unit (CCFU) under the Environment and Natural Resource Management Department in order to develop a comprehensive climate change response strategy for Zambia. Climatic hazards severely impacted agricultural productivity especially by small scale farmers. If the impacts of climate variability are not mitigated, the following scenarios could be expected to occur:

- an increase in the summer temperatures and lengthening of the dry season hence reducing the growing season and delaying the onset of rains;
- greater moisture stress on vegetation leading to land degradation
- drying up of water resources severely reducing the number of livestock owned by small-scale famers hence reducing their capacity to increase land cultivated due to a reduction in the number of animals owned which also serve for draught power;
- reduced number of small-scale farmers as rain fed agriculture becomes unsustainable due to increased climatic variation.
- highly leached soils in southern Zambia due to increased incidences of flooding leading to barren lands
- reduced soil fertility leading to an increase in incidences of shifting cultivation and massive clearing of vegetation leaving the soils unprotected to agents of erosion;
- increased incidences of flush floods in farms leading to crop failures.
- increased temperatures drying up of water from open surfaces like streams and rivers hence severely reducing the potential for irrigation and gardening

The formulated scenarios suggest urgent need for both coping strategies and adaptation measures to the adverse impacts of extreme climate variability. However, there is always a danger of overexploitation of natural resources if the coping strategies involve mining from the forests. Activities like charcoal production should not be encouraged as this tends to severely reduce the forests which play a very vital role in mitigating the long-term impacts of climate change. But if sustainable alternatives are not given to the affected communities, they are left with no choice but to over-exploit the forest resources.

Overall, the study has achieved the set out objectives though with varying degrees of success. It has examined the occurrence of variations in rainfall and temperatures in AER II. However, the lack of availability of comprehensive data made it difficult for comparisons among towns to be made. For example, Chipata which had all rainfall data for the entire period (1910 to 2009) could not be fairly compared to Monze with only 58 years of record. Consequently, the study could only establish comparisons over the period of time (1945-2009) when all towns had available data.. Many other towns had missing data for particular years which provided a challenge in conclusively establishing comparisons between different sub-regions of AER II. Higher success was scored when determining the most suitable maize variety for AER II as all the possible characteristics of the different varieties were compared to come up with the most suitable variety for the region. Similar success was scored when determining adaptation measures and coping strategies by small-scale farmers in AER II. When assessing the implications of climate variability on small-scale arable agriculture, the constructed scenarios are helpful in the event that no mitigation measures were done to combat climate variability. It is worth noting that the complexity and uncertainty of the (Brammer 1973)subject of climate variability makes it difficult to predict future changes with certainty.

CHAPTER SEVEN

SUMMARY, CONCLUSION AND RECOMMENDATIONS

This Chapter concludes the findings of the study on the climatic conditions of AER II for the past century and the implications thereof for small-scale farmers in this region. A summary and recommendations on adaptation alternatives for improving agriculture in the study area are also outlined.

7.1 Summary

Rainfall in Zambia is oscillatory in nature, although in recent decades there has been an increased frequency and intensity in droughts and floods. Analysis of observations of rainfall and temperature using Coefficient of Variation showed that AER II has been experiencing significant changes in received rainfall. The regression analysis showed that rainfall decrease was occurring at an annual rate of -1.09mm during the period 1910 to 2009 in AER II. Only Chipata in the region experienced increased rainfall at a rate of 0.79mm per annum during the same period. A reverse trend was observed from the analysis of temperature in the region which showed an increase especially after 1980. The region experienced 0.023℃ increase in the average annual temperature.. This meant that the region had been getting drier and hotter and this had contributed to the lengthening of the dry season and the shortening of the rainy season in many areas of AER II.

A variety of maize seeds recommended by the four private seed breeders (ZAMSEED, SEEDCO, MRI Seed and PANNAR) were investigated with respect to their adaptability to climatic conditions and potential yields. When all the recommended varieties were thematically analyzed with regard to their characteristics, it was found that ZAMSEED, ZMS 616 was a better variety for cultivation in AER II because of its adaptability to a range of climates and its resistance to disease was excellent, very good at drought tolerance and its maturity in 125 to 130 days was within the 150 days growing period for AER II. The variety also showed the highest potential yield of 10-12 t/ha. It was found to be adaptable to a range of climatic conditions compared to the other varieties because it tends to behave like an early maturing variety in times of moisture stress despite it being a medium maturing variety.

This study highlighted a high level of rainfall and temperature variability within the region and this gave rise to the need for effective and efficient coping strategies and adaptation measures as a way of surviving the three major climatic hazards common in Zambia, namely; droughts, floods and high temperatures. As a way of coping with these impacts many farmers have diversified their income generating activities. Instead of entirely depending on farming most farmers have shifted to activities like charcoal production and selling, brewing beer for sale, fishing, selling crafts, mats, livestock and even casual labour. Gardening for those farmers living near streams also served as a coping measure during droughts or floods. Most small-scale farmers have also diversified the type of crops they cultivate by using supplementary and complementary crops. Instead of simply growing maize, they also grow crops like Okra, Sorghum, Millet, Sugarcane and Beans. These crops are not easily affected by impacts of droughts and floods. Furthermore, farmers had established livelihood circuits which involved trade as a mode of sustenance. Activities which involve mining from nature such as charcoal production had often led to overexploitation of natural resources. However, in order to prevent overexploitation of resources there is a need to find a long-term solution to help them cope sustainably.

Therefore, the government has been largely emphasizing on two areas; (a) introduction of agro-ecological region specific maize varieties and (b) conservation agriculture (CA).

The government through the Ministry of Agriculture in partnership with the Conservation Farming Unit, Conservation Agriculture Programme and the Royal Norwegian Government has been supporting CF as a way to combating hazards of climate change by training and educating farmers on the benefits of CF over conventional agriculture.

In order to assess the implications of climate variability on small-scale agriculture in AER II, possible scenarios of implications of climate variability on small-scale agriculture were constructed. These scenarios show what is expected to happen in the event that nothing is done to avert climate variability and that the current climatic situation persists.

7.2 Conclusion

This study revealed that AER II in the period 1910-2009 and 1945-2009 had experienced significant rainfall and temperature variability, respectively with the southern part of Western Province (Sesheke) showing the highest rainfall and temperature variations. This increased variability had been prominent since the 1980s with the Eastern Province (Chipata) showing high variability while Mongu and Kaoma in the northern Western Province experienced the lowest rainfall and temperature variation. The annual rate of rainfall change was found to range from -3.01mm (Kalabo) to 0.79mm (Chipata) giving an average annual rate of rainfall reduction of -1.09mm. The annual rate of temperature change ranged from 0.005ºC for Senanga to 0.04ºC for Monze, giving an average rate of increase of about 0.023ºC. The maize variety ZMS 616, which was found to be more adaptable to the climatic conditions of AER II with higher potential yields, was highly recommended for farmers in the area to plant. As a response to climatic variations more attention ought to be placed on helping farmers to adopt conservation agriculture as a sustainable long-term measure rather than just emphasize on coping strategies. Overall, it is concluded that AER II had experienced significant climatic variability in the study period requiring concerted efforts in cushioning small-scale farmers from the whims of nature.

7.3 Recommendations

In view of the fore going research findings, discussion and conclusion made above, the following recommendations are made:

1. The Zambia Meteorological Department (ZMD) should increase weather stations and improve on recording and keeping of the rainfall and temperature data.Non-functional existing stations should be made functional and the closed stations reactivated.

2. The government should take the lead in promoting research in areas of climate variability and agriculture by increasing funding to research based institutions such as the University of Zambia, the Zambia Agriculture Research Institute (ZARI) and the Ministry of Science and Technology to bring out new knowledge on climate variability and agriculture. This increase in funding will not only promote climate variability based research but also research in plant breeding even in crops other than maize.

3. The government should continue encouraging the use of complimentary and supplementary crops such crops as millet, sorghum and cassava which can be used as adaptation measure by small-scale farmers during times of droughts and floods as well as promote research in these fields. At the same time there is need to shift from over-reliance on maize which is highly susceptible to climatic variation.

4. Climate data analysts and agro-meteorologists should advice small-scale farmers on best varieties for planting in their regions.

5. Small-scale farmers should be encouraged to adopt conservation agriculture as an adaptation measure to extreme climate variability. The extension officers of the Ministry of Agriculture and Cooperatives (MACO) should take the lead in ensuring speedy adoption of CA by small-scale farmers in their respective areas.

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APPENDIX 1

RECOMMENDED MAIZE VARIETIES IN ZAMBIA

Holder/ Agent	Maize Variety	Year Produced	Recommended Region for Production	Classification of Variety/ Maturity Group*
Zamseed	Pool 16	1995	I,II	Very Early Maturing
Zamseed	MM 441	1992	I,II	Early Maturing
Zamseed	GV 412	1998	I,II	Early Maturing
Zamseed	ZMS 402	2006	I,II	Early Maturing
Zamseed	MMV 400	1984	I,II	Early Maturing
Zamseed	GV 408	-	I,II	Early Maturing
Zamseed	GV 470	1998	I,II	Early Maturing
Zamseed	ZM 421	-	I,II	Early Maturing
ZARI-MACO	ZM 521	2004	I,II	Early Maturing
Zamseed	ZM 621	-	I,II	Medium Maturing
Zamseed	MM 501	-	I,II	Medium Maturing
Zamseed	MM 502	1984	II,III	Medium Maturing
Zamseed	MM 504	-	II,III	Medium Maturing
Zamseed	MM 601	-	II,III	Medium Maturing
Zamseed	MM 603	1984	II,III	Medium Maturing
Zamseed	MM 604	1984	II,III	Medium Maturing
Zamseed	ZMS 606	2006	II,III	Medium Maturing
Zamseed	ZMS 607	-	II,III	Medium Maturing
Zamseed	GV 512	-	I,II	Late Maturing
Zamseed	GV 704	-	II,III	Late Maturing
Zamseed	ZMS 737	2006	II,III	Late Maturing
Zamseed	MM 612	-	II,III	Late Maturing
Zamseed	MMV 600	-	II,III	Late Maturing
Zamseed	GV 607	-	II,III	Late Maturing
Zamseed	MM 62	-	II,III	Late Maturing
Zamseed	GV 67	-	II,III	Late Maturing
Zamseed	MM 752	1983	II,III	Late Maturing
Zamseed	GV 702	-	II,III	Late Maturing
Zamseed	GV 703	-	II,III	Late Maturing
Zamseed	GV 704	-	II,III	Late Maturing
Zamseed	GV 722	-	II,III	Late Maturing
Pannar Seeds	PAN 6363	1995	I,II	Early Maturing
Pannar Seeds	PAN413	2006	I,II	Early Maturing
Pannar Seeds	PAN 6823	2001	I,II	Medium Maturing
Pannar Seeds	PAN 5503	2002	II,III	Medium Maturing
Pannar Seeds	PAN 77	2003	II,III	Medium Maturing

Holder/ Agent	Maize Variety	Year Produced	Recommended Region for Production	Classification of Variety/ Maturity Group*
Pannar Seeds	PAN 6966	2004	II,III	Medium Maturing
Pannar Seeds	PAN6M-55	2005	II,III	Medium Maturing
Pannar Seeds	PAN 57	2005	II,III	Medium Maturing
Pannar Seeds	PAN 53	2006	II,III	Medium Maturing
Pannar Seeds	PAN 6243	1997	II,III	Medium to Late
Pannar Seeds	PAN 61	2000	II,III	Late Maturing
Pannar Seeds	PAN 14	2000	II,III	Late Maturing
Pannar Seeds	PAN 67	2001	II,III	Late Maturing
Pannar Seeds	PAN 6777	2001	II,III	Late Maturing
Pannar Seeds	PAN 69	2003	II,III	Late Maturing
Pannar Seeds	PAN7M-97	2004	II,III	Late Maturing
Pannar Seeds	PAN8M-91	2006	II,III	Late Maturing
Pannar Seeds	PAN8M-95	2006	II,III	Late Maturing
Seed Co.	SC 403	1999	I,II	Very Early Maturing
Seed Co.	SC 407	2001	I,II	Very Early Maturing
Seed Co.	SC 513	1999	I,II	Early Maturing
Seed Co.	SC 506	2004	I,II	Early Maturing
Seed Co.	SC 517	2004	I,II	Early Maturing
Seed Co.	SC 525	2006	I,II	Early Maturing
Seed Co.	SC 625	1998	I,II	Medium Maturing
Seed Co.	SC 621	1999	II,III	Medium Maturing
Seed Co.	SC 627	1999	II,III	Medium Maturing
Seed Co.	SC 602	2001	II,III	Medium Maturing
Seed Co.	SC 633	2002	II,III	Medium Maturing
Seed Co.	SC 637	2004	II,III	Medium Maturing
Seed Co.	SC 701	1997	II,III	Late Maturing
Seed Co.	SC 709	1998	II,III	Late Maturing
Seed Co.	SC 713	2001	II,III	Late Maturing
Seed Co.	SC 715	2001	II,III	Late Maturing
Seed Co.	SC 704	2003	II,III	Late Maturing
Seed Co.	SC 719	2005	II,III	Late Maturing
MRI Seed	MRI 455	1998	I,II	Early Maturing
MRI Seed	MRI 514	2001	I,II	Early Maturing
MRI Seed	MRI EP	2005	I,II	Early Maturing
MRI Seed	MRI 614	1998	II,III	Medium Maturing
MRI Seed	MRI 594	2000	II,III	Medium Maturing
MRI Seed	MRI 634	2000	II,III	Medium Maturing
MRI Seed	MRI 624	2001	II,III	Medium Maturing
MRI Seed	MRI 651	2002	II,III	Medium Maturing
MRI Seed	MRI 534	2002	II,III	Medium Maturing

Holder/ Agent	Maize Variety	Year Produced	Recommended Region for Production	Classification of Variety/ Maturity Group*
MRI Seed	MRI 694	2004	II,III	Medium Maturing
MRI Seed	MRI 644	2005	II,III	Medium Maturing
MRI Seed	MRI 734	1998	II,III	Medium Maturing
MRI Seed	MRI MP	2005	II,III	Medium Maturing
MRI Seed	MRI 724	1998	II,III	Late Maturing
MRI Seed	MRI 744	1998	II,III	Late Maturing
MRI Seed	MRI 711	2003	II,III	Late Maturing
MRI Seed	MRI 714	2003	II,III	Late Maturing

Adapted from ZASTA, 2008. *A dash (-) indicates lack of available data*.

APPENDIX 2

COMPUTATIONAL DETAILS FOR THE RAINFALL ANALYSIS OF VARIANCE

Decades	YEAR	Lusaka	Chipata	Sesheke	Kaoma	Mumbwa	Mongu	Senanga	Choma	Kabwe	Petauke	Monze	Mean
	1910		1001.8	667.512		806.45	879.602						**838.835**
	1911		1031	875.03		924.306	1013.714						**961.009**
	1912		798.83	499.364		605.536	798.83						**675.64**
	1913		1298.7	432.308		655.32	1020.064						**851.5985**
Decade 1	1914		699.26	693.674		1007.872	875.538						**819.0865**
	1915		803.15	633.476		723.646	756.158						**729.107**
	1916		792.73	434.848		702.31	801.116						**682.752**
	1917		1395	702.31		862.838	998.474						**989.6475**
	1918		1236.7	950.468		994.664	1103.63		1104.9				**1078.078**
	1919		926.85	934.974		832.358	927.354		716.026				**867.5116**
	1920		776.22	727.71		1146.048	894.588		980.44		795.528		**886.7563**
	1921		894.08	628.65	1115.1	1137.666	1207.262		1068.07		1156.462		**1028.192**
	1922		735.58	536.448	798.32	631.19	850.392		489.966		867.664		**694.436**
	1923		911.35	822.706	993.14	901.446	1113.028		798.322		987.552		**973.1058**
Decade2	1924		848.36	537.718	609.09	541.528	711.708		441.452		617.728		**631.1265**
	1925		1255.3	1378.2	1197.4	1089.914	1315.72		1243.584		1294.892		**1265.714**
	1926		1143.3	702.564	1122.7	1292.86	1086.612		727.71		1323.086		**1091.057**
	1927		712.22	623.062	938.78	745.744	930.91		959.104		692.658		**835.2084**
	1928		1062.2	505.46	999.49	856.488	1177.798		671.576		1060.704		**898.3416**
	1929		985.77	681.482	1004.8	838.962	915.416		631.19		1204.722		**860.5238**
	1930		921	632.46	1203.2	674.116	1150.112		806.704		1043.94		**871.8409**
	1931		966.47	472.948	700.02	769.366	722.63		628.65		930.656		**779.2438**
	1932		1033.8	682.244	1201.4	1347.978	1106.17	1136.65	1116.076		1053.338		**1053.77**
	1933		907.29	420.624	785.11	890.016		447.802	661.67	975.36	1036.828		**752.0247**
Decade 3	1934		1081.8	642.366	1066	684.276	962.406	849.376	705.358	844.55	1027.43		**900.7995**
	1935		880.62	423.164	1068.1	977.392	780.796	695.706	800.608	998.474	1114.298		**869.8576**
	1936		1122.7	736.854	1118.9	795.782	1075.182	863.854	803.91	750.062	845.058		**883.5736**
	1937		1157.7	507.746	757.43	722.376	1575.6	758.952	751.586	644.398	954.532		**898.3784**
	1938		948.69	367.03	841.76	911.352	612.4	809.752	713.486	829.564	848.36		**793.1964**
	1939	1146.8	1008.6	744.22	955.04	901.192	1295.4	900.176	721.868	1008.38	1106.424		**974.4922**
	1940	1069.8	1165.1	765.81	1408.2	1186.434	1327.15	752.856	1115.06	1313.18	960.374		**1112.52**
	1941	877.57	979.17	742.442	954.02	873.76	858.52	682.752	738.378	942.086	717.55		**865.251**
	1942	653.03	815.85	659.13	697.99	752.602	762.254	743.966	891.286	666.496	660.146		**747.7548**
	1943	989.08	1208.3	656.59	896.11	1026.16	766.826	739.394	1020.318	1149.35	900.684		**901.2978**
Decade 4	1944	966.98	1075.4	838.454	1020.1	676.402	1014.476	1127.506	927.1	815.848	634.238		**911.0133**
	1945	670.05	1061.2	437.134	760.22	817.88	911.352	592.074	666.496	865.632	1060.958	717.042	**805.7857**
	1946	617.98	864.36	690.118	715.52	745.744	763.016	684.022	747.776	856.234	739.394	714.756	**729.5075**
	1947	587.5	1187.4	302.768	787.91	664.21	695.452	749.808	509.524	699.77	1216.914	562.102	**742.6726**
	1948	773.94	1223.8	997.966	1010.7	1254.76	1140.46	1102.106	1111.504	1076.198	932.434	905.51	**1056.681**
	1949	649.99	779.3	683.26	675.64	969.264	604.266	610.616	688.594	647.192	690.88	532.13	**678.2408**
	1950	957.83	1270.8	711.708	1037.6	744.728	940.308	550.164	759.714	1011.428	1192.022	663.194	**908.3851**
	1951	578.1	753.9	737.9	890.52	710.692	998.22	796.036	626.6	1080.3	837.946	643.89	**804.1114**
	1952	1064.5	1221.2	961.9	1080.8	1038.86	1098.296	1331.976	767.6	1009.9	1167.384	1077.976	**1063.868**
	1953	999.24	972.1	735.3	1250.7	1021.588	1100.328	974.598	1107.2	1161.3	1321.562	1302.004	**1067.721**
Decade 5	1954	772.41	711.7	847.3	896.11	901.192	845.82	800.1	1091.7	848.6	748.538	683.768	**838.4495**
	1955	646.43	1257	1009.9	936.5	945.642	966.978	908.05	814.1	989.3	1101.852	966.216	**966.7397**
	1956	870.97	1011.7	783.1	854.2	929.64	1009.396	985.266	837.7	1034.3	1058.672	797.306	**961.1208**
	1957	773.94	1216.2	707.4	716.53	1025.398	1130.046	883.92	883.2	919	894.08	599.186	**912.964**
	1958	922.02	834.6	1542	995.17	1091.438	1352.55	1422.146	1115.8	1016.3	1131.316	1124.712	**1101.692**
	1959	738.89	851.9	748.3	1504.2	1083.564	1171.702	988.314	787.4	1194.8	949.452	842.01	**1009.766**

Decades	YEAR	Lusaka	Chipata	Sesheke	Kaoma	Mumbwa	Mongu	Senanga	Choma	Kabwe	Petauke	Monze	Mean
Decade 6	1960	779.02	981.5	556.8	926.34	1080.262	908.812	754.38	779.3	779	861.568	722.63	**828.242**
	1961	789.18	1225.3	664.7	1058.9	1121.664	1081.278	696.468	844	1195.8	1149.858	849.376	**950.2463**
	1962	839.22	1292.1	499.1	1022.9	967.994	1042.162	581.66	1212.8	1377.9	1380.744	625.602	**1007.375**
	1963	964.44	1172.5	770.6	1121.2	1052.576	1029.208	830.58	704.8	983.2	925.83	941.324	**973.3997**
	1964	643.89	909.6	492.3	703.07	832.358	805.18	749.046	768.3	823.2	871.474	735.584	**793.1842**
	1965	894.33	1030.2	516.6	812.8	686.308	656.59	505.714	661.7	877.8	879.856	635	**736.9085**
	1966	741.93	796	611.9	975.36	856.996	1074.674	814.324	655.8	779.5	762	654.05	**815.7249**
	1967	799.85	1019.6	611.4	911.86	710.946	731.266	666.242	869.9	988.3	998.728	692.658	**814.9298**
	1968	784.1	817.6	835.4	744.47	847.344	1078.484	1006.856	692.9	877.6	786.892	658.368	**851.1334**
	1969	877.82	1242.1	705.6	1306.8	1144.778	1150.62	982.472	1132.8	1463.3	1027.938	595.122	**1046.616**
Decade 7	1970	707.39	877.6	481.1	872.74	933.704	804.164	614.172	674.6	635.3	833.628	763.016	**730.3535**
	1971		1290.6	536.2			847		552.2	778.3	1032.3		**839.4333**
	1972		893.8	920.5			977.7		781.3	686.6	739.4		**814.0143**
	1973	486.6	967.9	379			770		626.3	879.5	915.9		**696.225**
	1974	1524.5	1348.2	1068.1			1140.7		1419.5	1216.5	1101.1		**1209.925**
	1975	834.6	755	787.3			1037.4		682.8	732.4	668.2		**781.6**
	1976	835.4	978.3	580.2			1085.1		804	954.6	1271		**916.75**
	1977	920.4	1083.8	1087.5			846.2		723.6	738.1	990.7		**886.3**
	1978	1266.5	1476.6	1039.2		1127.6	1310.9		1086.9	1444.3	1318.8	1121.4	**1225.27**
	1979	710.3	1011.3			832.5	880.2		1045.6	803.5	640.4	821	**838.1556**
Decade 8	1980	618.6	1000.3			418.7	883.7	712.3	795.5	990.3	1197.7	599.3	**857.32**
	1981	974.5	1057.3			905.5	925.7	909.1	724.3	788.4	938.7	751.9	**854.93**
	1982	772.8	662.7	173.7		891.7	724.3	595.2	510.5	925.2	977.2	681.8	**707.5909**
	1983	693.3	880	487.3		924	761	705.4	737.9	952.1	739	701.5	**756.4545**
	1984	623.2	822.9	624		800.1	752.5	611.3	562.9	872.4	1046	566.2	**743.3818**
	1985	812.6	1291.8	625		774.6	763.3	492.4	829.2	955	1197.2	809.1	**880.4636**
	1986	1044.4	1027.2	650.4	990.7	1037.6	937.8	866.1	1224.3	923.6	1077.1	740	**983.275**
	1987	574.4	881.5	559.2	707.7	825.7	748.8	563.8	375.6	625.7	564.5	572	**623.2692**
	1988	588.4	1035.6	638.1	847.1	969.7	833.6	865.2	668.2	602.9	986.4	624.6	**816.3231**
	1989	1222.7	1253.2	772	1001.9	1300.7	1074.6	785.5	1078.8	837.6	1402.7	839.4	**1050.138**
Decade 9	1990	837.5	920.9	623.9	764.4	959	876.2	767	851	862	826	826.4	**809.4692**
	1991	1033.9	707.9	484.5	746	702.4	966.1	852.4	593.9	804.3	773.9	636.4	**767.7308**
	1992	615.5	655.6	514.8	688	438.5	623.5	699.3	527.3	789	647.6	650.3	**623.1**
	1993	644	989.1	688.9	973.9	783.8	1256.7	764	773.6	772	1256.2	627	**889.1**
	1994	433.5	717.1	577.1	673.5	602.3	620.2	528.3	481.5	673.1	673.4	545.5	**601.8923**
	1995	314.8	733	330.7	630.4	398.6	707.7	660.9	551	636.7	740.3	524	**579.9154**
	1996	710.5	1042.2	416.6	817.9	931	726.5	770.2	859.3	635.5	969.2	736.8	**773.6385**
	1997	813.2	1132.7	611.4	876.6	999.2	941.4	899.8	1021.3	913.9	1131.7	880.9	**872.0077**
	1998	843.4	851.9	457.8	775.3	629.3	1120.7	602.5	763.6	780.8	841.7	691.9	**746.4538**
	1999	754.5	1081.7	672.2	811.8	750	865.3	527.6	611.3	830.1	757.5	759.7	**749.8231**
Decade 10	2000	1190.4	695.2	604.9	1037	1118.5	1228.5	771.8	1048.9	1044.7	1307.4	829.5	**976.3615**
	2001	958.6	1404.4	552.2	1029.7	966.1	816.5	594.8	836.6	1162.6	917.7	868.4	**913.2231**
	2002	654.2	917.2	402.1	778.4	572.3	1060.2		572.1	690.3	1038.7	456.3	**708.7833**
	2003	883.3	1055.1	389.5	870	405.4	813.8		747.1	1127.9	902.7	868.4	**860.9833**
	2004	1138.8	1099.1	950.8	935.2	724.3	984.4		892.2	992.3	993.1	772.8	**967.5818**
	2005	495.2	1207.8	317.9	1064.4	399.8	682.2		622.4	722.2	593.9	606.6	**687.2909**
	2006	804.3	1452.3	941		844.4	842.5		990.1	761.3	689.7	754.9	**902.93**
	2007	935.9	1931.7	551.5	871.1	1151.5	1096.5		1070.1	1245.9	1104.4	1074.1	**997.625**
	2008	964.8	1680.7	696.9	560	1120.2	1579.5	520.7	501.2	408.3	844.6	981.7	**826.0308**
	2009	847.1	626.4	468.8			765.8				962.8	717.7	**731.4333**

A blank indicates lack of available data for that particular year

Decadal ANOVA Rainfall Data Analysis

Source	DF	SS	MS	F	P
Factor	9	307233	34137	2.94	0.036
Error	90	1586016	17622		
Total	99	1893249			

APPENDIX 3

COMPUTATIONAL DETAILS FOR THE TEMPERATURE ANALYSIS OF VARIANCE

Decades	Year	Sesheke	Mumbwa	Choma	Kabwe	Chipata	Senanga	Monze	Kaoma	Petauke	Mongu	Lusaka	Mean
	1945					22.85							
	1946					21.8							
	1947					22.05							
	1948					21.95							
	1949					22.65							
	1950	21.35		19.3	19.35	21.2				21.6		20.15	**20.74**
	1951	21.6		19.45	21.3	21.6				22.1		21	**21.26**
	1952	21.4		19.9	20.4	22.2				21.95		20.75	**21.24**
	1953	20.95		19.3	20.4	22.25				21.95		20.05	**20.89**
Decade 1	1954	21.3		19.85	20.8	22.05				22.15		20.55	**21.21**
	1955	21.6		19.95	20.05	21.95				21.7	22.3	20.3	**21.21**
	1956	21.45		19.45	20.75	21.55				21.35	21.7	20	**20.96**
	1957	22.3		19.45	21.35	22.65				22.35	22.4	21.05	**21.88**
	1958	21.1		18.75	21.1	22.55				22	22	20.4	**21.19**
	1959	21.55		19.15	20.7	22.5				22.25	22.4	20.8	**21.45**
	1960	21.45		18.65	20.65	22.3				22.2	22.25	20.3	**21.22**
	1961	21.5		19.15	20.8	22.3				22.1	22.35	20.45	**21.3**
	1962	21.1		18.75	20.45	21.9			21.3	21.75	22.05	20.15	**20.97**
	1963	20.15		18.5	20.3	21.65			20.6	21.55	21.8	20	**20.61**
Decade 2	1964	21.1		18.4	20.4	21.9			20.7	21.8	22.05	20.05	**20.83**
	1965	20.75		18.2	20.15	21.55			20.75	21.6	22.2	20.05	**20.73**
	1966	21.5		18.8	21.05	22.6			21.35	22.55	22.25	20.95	**20.43**
	1967	21.6		18.8		22.05			21.15	22	22.6	20.35	**21.27**
	1968	21.8		19		21.9			21.2	22.2	22.15	20.35	**21.41**
	1969	22.2		19.2		22.4			21.35	22.4	22.5	20.55	**21.58**
	1970			19.1		22.3			21.4	22.4	22.95	20.25	**21.74**
	1971			18.75		21.75			21.15	22	22.7	20.6	**21.27**
	1972			19.35		22.2			20.85	22.35	22.3	20.3	**21.37**
	1973	22.1		19.3	20.75	22.2			22.05	22.4	23.1	21.4	**22.15**
Decade 3	1974	21.1		18.75	20.05	21.8			20.7	21.85	22.15	19.7	**21.17**
	1975	20		18.95	20.55	22			21	22.3	22.6	20.35	**21.3**
	1976	21.1		18.8	20.1	21.9			20.5	21.55	21.9	19.9	**20.9**
	1977	21.9		19.65	20.85	22.35			21.55	22.7	23.05	20.85	**21.86**
	1978	20.9	20.95	19.1	20.6	22.15		20.55	21.1	22.65	22.35	20	**21.23**
	1979	21.7	21.05	19.15	20.65	22.25	22.8	20.85	21.2	22.6	22.65	19.85	**21.66**
	1980	22.4	21.35	19.05	20.25	22.2	22.85	21.15	21.35	22.9	22.75	20	**21.76**
	1981	22.64	20.15	18.9	20.4	22.4	22.85	20.8	21.05	22.5	22.5	20	**21.55**
	1982	22.55	21.85	19.8	20.9	22.3	23.15	21.15	21.7	22.35	22.95	20.3	**22.03**
	1983	22.35	21.2	20.2	21.7	23.35	23.5	21.95	22.2	23.75	23.45	21.4	**22.7**
Decade 4	1984	21.95	21.5	19.6	21.05	22.6	23.1	21.6	21.65	22.9	22.85	20.55	**22.2**
	1985	22	21.05	19.35	20.3	22.2	23.1	20.8	21.4	21.9	22.9	19.85	**21.69**
	1986	21.75	20.5	19.15	20.5	22.2	22.4	20.8	21.3	22	22.6	19.65	**21.47**
	1987	22.6	20.5	20.5	21.65	22.85	23.3	22	22.4	22.55	23.55	21.05	**22.6**
	1988	21.75	20.35	19.55	21.1	22.8	22.8	21.35	21.95	22.5	23.1	20.85	**22.14**
	1989	21.85	21.05	19.8	20.9	22.2	23	21.3	21.85	22.1	22.85	20.55	**21.94**
	1990	22.25	20.9	20.2	21.2	22.95	23.25	21.9	22	22.85	23.35	20.65	**22.41**
	1991	21.1	20.65	19.45	20.85	22.5	22.6	21.1	21.3	22.6	22.75	20.65	**21.84**
	1992	20.9	21.35	20.5	21.65	23.45	23.2	22	22.25	23	23.35	21.35	**22.66**
	1993	21.95	20.95	20	21.3	22.8	22.7	20.85	21.05	23.15	23.05	20.8	**22.08**
Decade 5	1994	21.85	20.1	19.7	21.4	23.1	24.4		21.45	23.55	23.15	21.9	**22.42**
	1995	23.2	21.4	20.65	21.55	23.55	24.15	22.95	22.7	23.45	24.05	21.6	**23.02**
	1996	22.4	21.3	20	21.25	22.85	23.7	21.45	22.35	22.6	23.8	21	**22.44**
	1997	22.7	21.7	20	21.15	23.9	23.15	21.05	22.4	22.55	23.45	21	**22.52**
	1998	22.85	21.8	20.45	21.75	23.1	22.95	22.15	22.2	23.4	23.6	21.85	**22.8**
	1999	22.75	20.9	19.7	20.95	22.7	23.45	21.3	21.7	22.5	22.9	21.05	**22.2**
	2000	22	21.6	19.75	20.95	22.7	22.95	21.8	21.8	22.4	22.95	21	**22.16**
	2001	21.9	22.2	20.65	21.35	23	23.4	21.95	22.05	22.9	23.65	21.6	**22.73**
	2002	23.2	21.15	20.55	21.85	23.3		22.55	22.35	23.3	23.8	22.25	**22.83**
	2003	22.55	19.95	20.3	20.5	22.1		21.2	22.3	23	23.3	20.8	**22.14**
Decade 6	2004	20.5	22.7	20.7	22.25	23		23.4	21.95	22.7	22.8	20	**22.68**
	2005		21.05	21.1	23.8	23.7		22.6	23.3	23.75	24.05	22	**20.04**
	2006	22.25	20.3	19.3	20.9	23.15		21.6		23.8	23.3	20.45	**22.33**
	2007	21.9	21.85	20.4	21.75	23.8	23.35	21.8	22.25	23.15	23.6	20.8	**22.81**
	2008		20.85	19.9	21.4	23.15	23.2	21.35	22.55	23	23.3	20.85	**22.67**
	2009		21.2	20.15	21.75	22	21	22.5	22.6	24.1	23.95	20.95	**22.53**

A blank indicates lack of available data for that particular year

Decadal ANOVA Temperature Data Analysis

Source	DF	SS	MS	F	P
Factor	5	17.261	3.452	15.17	0.001
Error	54	12.287	0.228		
Total	59	29.548			

APPENDIX 4

SEMI-STRUCTURED INTERVIEW SCHEDULE FOR OFFICIALS AT THE DEPARTMENT OF AGRICULTURE HEADQUARTERS AND THE CLIMATE CHANGE FACILITATION UNIT

Personal Information:

1. Name…………………………………………………………………………………

2. Position………………………………………………………………………………

3. Contact details…………………………………………………………………………

Information on Climate Change

1. What do you understand by the term Climate Change?

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2. Do you think Zambia is experiencing any Climate Change?

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   Why do you say so?

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3. Do you have facilities in place to project the expected effects of Climate Change at a particular time?

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If so how do you obtain information about expected impacts of Climate Change from these facilities?

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4. What would you say are the factors affecting optimum conditions for maize growing apart from Climate Change?

Factor	**Impacts on optimum conditions for maize growing**

5. What problems do farmers encounter as a result of changes in climatic conditions?

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6. How long have these problems been affecting farmers?

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7. What has been the government's response to these problems affecting farmers?

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8. How is the government mitigating the impacts arising from Climate Change?

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9. What short-term and long term measures are being/have been put in place to mitigate the impacts of Climate Change?

Short-term……………………………………………………………………………………
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Long term……………………………………………………………………………………
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10. Has the government invested in the research on Climate Change?

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If so, what kind of research is the government supporting?

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11) Are there any particular maize varieties you have been promoting to small-scale farmers? If so, which ones and why?

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Or did you start promoting different crops all together? If so, which ones and why?

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12. What would you say are the implications of Climate Change on Maize growing?

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End of Interview

Ask for these documents:

- **Action Plan**
- **National Agricultural Policy**
- **National Adaptation Plan of Action on Climate Change**
- **Any other relevant documents**

APPENDIX 5

SEMI-STRUCTURED INTERVIEW SCHEDULE FOR OFFICIALS AT THE DIFFERENT SEED BREEDING COMPANIES IN ZAMBIA

Personal Information:

1. Name……………………………………………………………………………………

2. Position…………………………………………………………………………………

3. Contact details…………………………………………………………………………

Information on Maize Seed Breeding

1. How long has your company been involved in maize seed breeding?

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2. How many maize seed varieties have you bred since then?

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3. What types of maize seed varieties have you been promoting?

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4. How long does it take for these varieties to reach maturity?

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5. Which of these varieties would you recommend for cultivation in Choma area and why?

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6. How is the plant breeding process conducted by your company?

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7. Do you utilize any biotechnology tools in crop improvement and if so, which ones?

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8. What is your source of germplasm used in crop improvement?

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9. What criteria is used when naming your maize varieties?

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10. Would you say the government has been supportive of the plant breeding sector in Zambia?

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If so, how has the government been supporting this sector?

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11. What has your company been doing to ensure the farmers buy the right maize varieties for their area?

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12. Which particular maize varieties are you promoting for the 2010/2011 growing season and why these?

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13) How would you rate the vulnerability of particular maize varieties to changes in climate conditions?

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14. What would you say are the implications of climate change on Maize growing?

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End of Interview

Ask for these documents:

- **Action Plan**
- **National Agricultural Policy**
- **National Adaptation Plan of Action on Climate Change**
- **Any other relevant documents**

APPENDIX 6

SEMI-STRUCTURED INTERVIEW SCHEDULE FOR FARMERS

Personal Information:

1. Name…………………………………………………………………………………

2. Type of Farmer………………………………………………………………………

3. Contact details…………………………………………………………………………

Information on farming done

1. How long have you been a farmer?

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2. How large is your farming area?

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3. What crops do you cultivate and why these?

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4. What maize varieties do you cultivate and why?

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5. Have you been changing the kind of maize variety you have been cultivating?

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If yes, how long does it take you to change from cultivating one maize variety to another and why do you change?

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6. Which maize varieties would you say has been giving you the best yields?

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7. What is the approximate yield realized from the different maize varieties you plant?

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How do you account for the difference in these yields?

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8. What factors do you consider when choosing one maize variety over the others?

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9. How would you rate the vulnerability of particular maize varieties you plant to impacts of droughts and floods?

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10. What other crops would you recommend for cultivation in Choma area under the current climatic conditions and why these?

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Information on Climate Change

1. Have you been experiencing any droughts? Floods?

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2. If yes, since when?

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3. How have you been coping in times of:

a)Droughts………………………………………………………………………………………

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b) Floods………………………………………………………………………………………

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4. What adaptation measures have you put in place to ensure you are not adversely affected by future occurrences of:

a)Droughts………………………………………………………………………………………

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…………………………………………………………………………………………
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b)Floods………………………………………………………………………………………

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5. Generally, what problems do you farmers in this area encounter as a result of droughts and floods?

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6. When did you start experiencing these problems?

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7. What has the government done to help you cope with these problems?

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8. Have you received any assistance from NGOs during your times of droughts and floods?

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If yes, what kind of assistance and by which NGOs?

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9. What short-term and long term measures have you put in place to mitigate these impacts of climate change?

Short term…………………………………………………………………………………

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Long term…………………………………………………………………………………

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10. How have you adapted to these impacts of climate change?

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11. How would you rate the vulnerability of particular maize varieties you plant to changes in climate conditions?

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12. What particular maize varieties have you been cultivating and why?

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13. What other crops would you recommend for cultivation under the current climatic conditions in Choma and why?

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End of Interview