ADAPTATION OF ZAMBIAN AGRICULTURE TO CLIMATE CHANGE - A COMPREHENSIVE REVIEW OF THE UTILISATION OF THE AGRO-ECOLOGICAL REGIONS

A Review For Policy Makers

J S Phiri, E Moonga, O Mwangase, G Chipeta
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Foreword

The Zambia Academy of Sciences (ZaAS) was established for a purpose of “Promoting Excellence in Scientific and Technical Endeavours” in Zambia. I am glad to see that as a young academy, we are on the right path towards fulfilling our objectives and especially our role of advancing the cause of science and technology. I would like to reiterate that ZaAS is ready and willing to contribute, as scientists in the sustainable development of our country as we strongly believe that Zambia can truly develop only through advancement in science and technology.

This Policy Brief is in line with the aspirations of the Constitution of the Academy and specifically Articles 4 and 5 that empowers the Academy to initiate studies or can be requested by stakeholders including Government or persons to undertake such research for purposes of scientific advice, guidance or for purposes of advancing science and technology in Zambia.

It is in recognising this important role that the first Policy Brief addresses climate change and food security. Climate change is a challenge universally considered the single most threatening situation facing mankind today since time immemorial. This Policy Brief tackles impacts of climate change on agriculture and food security as well as Zambia’s long time reliable Agro Ecological Regions Zoning that has been used since late 1970s to guide planning, agricultural production, scientific research and investment. The reliability of this Tool and the entire agriculture sector is threatened by climate change.

Our decision to undertake a comprehensive review of the impact of climate change on Agro Ecological Regions could not have come at a better time than now when the country has just experienced one of worst attacks of army worms invasion ever recorded in the history of our country. The army worm attack follows a year when some parts of Zambia received late rains or received too much rain in a short space of time. The combined effects of army worms attack and rainfall pattern has dealt a serious blow to the country’s food security goals as well as pushing back gains made towards the attainment of MDGs especially MDG 1 on food security and reducing poverty. Recently, some outskirts of Lusaka have been infested with a potential zoonotic situation with the outbreak of rodent fleas that have invaded houses and we have briefly discussed plague conditions that allow for outbreak of bubonic plague. These challenges the nation has faced just confirm to the need for strengthening scientific research.

When I proposed to my colleagues that we undertake a review of Agro Eco-Regions in view of climate change, I was encouraged by the response and unanimity in our agreement and therefore had no doubt in my mind that we had decided on the right subject for our first Policy Brief Document. I am therefore grateful to my colleagues led by James S Phiri who have worked hard to deliver this document whose use will have far reaching benefits to the Government of Zambia as well as to other stakeholders both in agriculture and beyond.

This work could not have been done without the support of our partners; the Network of African Science Academies (NASAC), InterAcademy Panel and the Germany Academy of Sciences the Leopoldina and the German Federal Ministry of Education and Research (BMBF) whom we are greatly indebted.
Finally, I would like to state that the Zambia Academy of Sciences is a not-for-profit and non-political organization and also declare that all persons involved in this work have no competing interests.

Mwananyanda Mbikusita Lewanika, PhD
President,
Zambia Academy of Sciences,
Lusaka, Zambia.
13th April 2013
Executive Summary

Countries of the Southern African region including Zambia have experienced negative impacts associated with climate change especially in the recent past decades where the frequency and severity of extreme events such as droughts and floods have increased. Average temperatures have increased but precipitation levels have reduced. The pattern of rainfall has changed with a trend of late onset and early cessation of rainy season. These changes in precipitation, temperatures and GHGs, have serious implications for natural systems and farming systems as well as crop or plant growing season and will have a profound effect on natural systems and economic sectors including agriculture, livestock epizootics and human health diseases including zoonotics. In some areas agricultural yields will improve while in others, productivity and yields will reduce. This picture is true at global, continental, sub-continental or regional and national levels. The impacts of climate change show variability according to different Agro-Ecological Regions (AERs) of the continents and within countries.

Zambia has three Agro Ecological Regions (AER I, AER II and AER III) which have been used as Policy and Adaptive Management Tool in agriculture planning and investment. The impacts of climate change in the country’s Agro Ecological Regions are evidenced through observed gradual increases in average temperatures averaging 0.3°C per decade and declining trend in amounts of rainfall. There is an observed declining rainfall pattern across Zambia with the Southwest Region (largely AER I and Western parts of AER II) receiving less rain and experiencing higher frequency of climate extreme events; droughts and flash floods compared to other AERs of the country. An increasing temperature and reducing precipitation scenario along with other environmental factors, contribute to increased evapotranspiration, negatively affect growing season, leads to lower crop yields especially of Zambia’s staple food crop maize and seriously threatens national food security with the poor rural people most likely to be most affected.

Zambia’s agriculture output is projected to decline by 30% by 2080 and the country’s GDP growth rate is expected to be lower by 4% over a ten year period 2006-2016 under the current climate change scenario unless adaptation measures are applied and the Agriculture Policy is climate proofed.

The use of the AERs in health sector is not very clear and requires more specific and detailed studies to establish any link.

As a result of some observed shifts in rainfall amounts and patterns, the increasing temperatures and increased frequencies of extreme climate events, Zambia’s Agro Eco Regions’ geographical boundaries and climatologic characteristics could have changed or shifted as has happened to Zimbabwe’s AERs. Therefore, the AERs may not be as effective for supporting policy and adaptation in agriculture and should be revised to reflect current and future scenarios under climate change in order to develop more productive and sustainable agriculture according to prevailing conditions.
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Abbreviations

AERs  Agro-Ecological Regions
AMCEN  African Ministers Conference on Environment
CAADP  Comprehensive African Agricultural Development Program
CSA  Climate Smart Agriculture
CSO  Central Statistics Office
ENSO  El-Nino/La Nina Southern Oscillation
FAO  Food and Agriculture Organization of the United Nations
FMD  Foot and Mouth Disease
FNDP  Fifth National Development Plan
GDP  Gross Domestic Product
GHG  Green House Gases
GRZ  Government of the Republic of Zambia
IESTO  Institute for Eco-Development Strategies and Toxicology
IPCC  Inter Governmental Panel on Climate Change
ITCZ  Inter Tropical Convergence Zone
NAPA  National Adaptation Plan of Action
NASAC  Network of African Science Academies
NEPAD  New Partnership for African Development
SEI  Stockholm Environment Institute
SNDP  Sixth National Development Plan
SOI  Southern Oscillation Index
UN  United Nations
UN-UNSG HLP-GS  United Nations Secretary-General’s High-level Panel on Global Sustainability
UNZA  University of Zambia
ZaAS  Zambia Academy of Sciences
ZARI  Zambia Agriculture Research Institute
ZMD  Zambia Meteorology Department
1.0 Introduction

The Inter-Governmental Panel on Climate Change (IPCC) in their vulnerability assessment reports have consistently reported the vulnerability of agriculture to climate change observing the variability of impacts in different regions while stating that the developing countries especially in Africa would be disproportionately. This is because besides receiving the most direct negative effects such as low precipitation, increased frequency of severe droughts and severe floods the continent has weak capacities for adaptation (AMCEN 2012). Studies on climate change suggest significant negative impacts of climate change on agriculture, health and many other economic sectors.

One of the features and challenges of the African continent with regards its vulnerability to climate change is related to its variability in geophysical-climatic features (Rockefeller Foundation 2006) which form climatic regions that are influenced by different factors. As an example, while in Eastern Africa, the ENSO is a major feature in the sub-region’s climate variability, in Southern Africa including Zambia, rainfall is influenced by many factors including the Inter-Tropical Convergence Zone (ITCZ), the Southern Oscillation Index (SOI), the Antarctic Oscillation (AAO) as well as the ENSO (AMCEN 2011). These variations in the geo-physical and climatic characteristics can however be aggregated based on similar characteristics and be classified, defined, recognized and identified as a region or zone. Therefore, In this document, the term Agro-Ecological Region is used interchangeably to mean Agro-Ecological Zones. The FAO (1999), defines Agro-Ecological Zone as a “land resource mapping unit, defined in terms of climate, landform and soils, and/or land cover, and having a specific range of potentials and constraints for land use.” The development of AERs is beyond the scope of this study suffice that it involves a complex detailed process of looking at many different factors including bio-physical, environmental and how they interact with the socio-economic environment. The ultimate aim is to produce as much as possible distinct units that have close similarities in terms of their use or potential use, characteristics or determinant climatic and environmental parameters that would maximize crop growth and yields. Africa has 16 agro-ecological zones or agro-ecological regions that will be impacted differently by climate change (Niggol Seo et al., 2008).

Zambia like many developing countries is highly vulnerable to climate change. Agriculture and health sectors are among the most vulnerable to climate change. Among the agriculture adaptation strategies that have been used in Zambia, is the Agro-Ecological Regions (AERs), a policy and an Adaptive Management Tool that was developed in the late 1970s and early 1980s based on rainfall, temperatures and soil characteristics but without climate change considerations. Therefore, in the face of climate change scenarios, the assumptions underpinning the AERs may not hold and its effectiveness as an adaptation tool in agriculture is being questioned. The Project will review the possible impacts of climate change on the effectiveness of AERs and make necessary recommendations based on the findings of this review. In this review, the period of observation for Zambia spans six decades, 1950-2010.

2.0 Evidence of Climate Change

Climate change is defined as a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer (UN-SG-HLP-SG 2012). Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. Variations in seasonal weather patterns are normal and expected. The effects of such variability are manifest across a range of natural systems and human
activities. Left to natural systems, these variations are assumed to present fluctuations about an essentially stable average climate. However, it is now settled that the high concentration of certain greenhouse gases in the atmosphere have primarily been as a result of human activities and is highly probable that this is responsible for global warming/climate change and the climate extremes being experienced in the past century (IPCC-SPM, 2012). Unless, GHGs levels are stabilized to agreed thresholds levels, global warming will continue with temperatures rising to dangerously high levels that will threaten the very survival of the earth.

2.1 Global Level

Global average temperatures are expected to continue rising as a result of a continued build up of GHGs. The projected temperature rises range between 2.4 to 6.4 degrees Celsius by the year 2100 under increasingly high emissions but under low emissions, the range is 1.1 to 3 degrees Celsius by the year 2100. Rainfall patterns on the other hand are expected to significantly vary across continents and even within countries. The IPCC has consistently projected variations in precipitation levels almost on a North-South divide with the North generally expected to receive more rainfall compared to the South. These changes in precipitation, temperatures and CO$_2$ will have a profound effect on natural systems and economic sectors including agriculture and health. In some areas the effects will be positive while in others, the impacts will be more negative. From the first Assessment Report, the IPCC concluded that; The balance of evidence suggests a discernible human influence on global climate. This conclusion has had such profound influence on climate change debate and the subsequent international agreements including the wording of the UNFCC and its Kyoto Protocol and almost all international programs of action aimed at mitigating the current and projected impacts of climate change. The gravity of potential impact is given by the HLP that noted that the current path of GHG emissions is on course for a likely temperature increase of between 2.5 and 5 degrees Celsius by the end of the twenty-first century. Such increase would put millions of lives especially in the developing countries at great risk from increased malnutrition, disease or physical injuries associated with extreme climate events (UN-SG HLP-GS 2012).

Thus, the IPCC in their Fourth Assessment Report summarize and conclude that; Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level”

2.2 Regional Level

The Southern African region including Zambia has experienced negative impacts associated with climate change especially in the recent past decades where extreme events such as droughts and floods and their severity have occurred more frequent than usual compared to past similar length of periods.

There is also a notable associated reduction in precipitation as a result of extreme droughts. Shongwe et al. (2009) observes not only a reduction in precipitation but also changes in the pattern of onset of rain where there is a notable delay in the onset of rainy season and early cessation which has serious implication for systems including farming systems as well as crop or plant growing season. On the basis of these observations, it can be said that AERs are changing or shifting. In addition, the region is experiencing increasing average and maximum temperatures (Ziervogel et al., 2008).

2.3 National Level

According to recent studies, climate change influenced trends have been observed and the trends include; changes in the start and cessation of the rainy seasons, increased or decreased average precipitation and increasing average and maximum temperatures (NAPA 2007; Ngoma 2010). It has
been observed that the start of the rainy season has changed generally tending towards late start and early ending resulting in shortened crop growing season. As a result of some observed shifts in increasing temperatures and rainfall patterns, there is credence in questioning the status of the existing AERs because the evidence based on meteorological data and farming systems suggest that the geographical zones of the current AERs may have shifted.

2.3.1 Historical Temperature Trends 1950-2010

The observed and predicted global trends in increasing average temperatures over time, has similarly been observed in Zambia (CEEPA, 2006; NAPA, 2007; Thurlow et al., 2008; ZMD, 2013). There has been a steady rise in average maximum temperatures since the baseline year (1950) for this review. According to the latest meteorological data (Figure 1) provided by the Zambia Meteorology Department (ZMD), the temperature rise averages 0.33°C per decade in the first three decades (1950-1980) but from 1950-2010, the increase is approximately 0.6°C per decade for the six decades under review and consistent with Neubert et al (2011).

Figure 1 Annual Temperatures (1950-2010)

Other studies have equally shown a steady rising trend in temperature averaging 0.3°C per decade. Studies undertaken at three different sites in three AERs, Yamba et al (2009), observed increase in temperature at the rate of 0.34°C, 0.26°C, and 0.48°C per decade for Kapiri Mposhi, Mwansabombwe and Sesheke, respectively.

2.3.2 Rainfall Trends between 1950 and 2010

Studies undertaken by the Environmental Council of Zambia under the United States Country Studies Program (USCSP) predicted a declining rainfall pattern over the country (USCSP 1999). Recent

1 Source ZMD 2013

Data provided by ZMD 2013
assessment of historical climate data shows a declining rainfall pattern across the country. This trend has shown a sharp decline especially starting in the 1980s (Figure 2). This observation has been made by several studies showing that the country is getting drier with a North-South declining gradient.

Figure 2 Declining Annual Rainfall Trend 1980-2010

![Annual Rainfall (mm) 1980-2010](image)

Source: ZMD 2013

In the study by Yamba et al (2009), there was a decline of rainfall in Mwansabombwe in (AER III) and Sesheke (AER I) but showing fluctuation for Kapiri Mposhi. Moonga E (2011) citing Victor Shitumbanuma indicates, comparably, a decrease of mean seasonal rainfall distributions over Zambia for the period 1940 to 1970 and 1971 to 2005 for selected stations West of longitude 28.5°E as a function of the latitude. Several other studies have shown that the country is receiving less rains on the average but as shown in the study by Yamba et al. (2009), the decline is not uniform as some areas have shown an almost constant pattern while others could have become wetter. However, there is general agreement that the South-Western region of the country has become drier and has experienced a higher frequency of climate extreme events; droughts and flash floods that have resulted in changes in shortened crop growing seasons (Mwale et al., 2007; Neubert et al., 2011) and crop damages.

A combination of rising average temperatures (Figure 1) and declining rainfall (Figure 2), has resulted in considerable hotter and drier conditions that have made the semi-arid drier AER I to become even drier and affecting the AER characteristics. These conditions have extended to some parts of Region II thereby raising a justifiable reason to re-classify the AERs map of Zambia on the basis of climatological data and conditions.

Data provided by ZMD 2013
2.4 Major Observations

- The IPCC has stated that; climate has changed over the past century and is expected to continue to change in the future although still with many uncertainties but with the balance of evidence suggesting a discernible human influence on global climate.
- An increasing body of observations gives a collective picture of a warming world and other changes in the climate system with average surface temperature increase of 0.6°C in the 20th century. In this context, Zambia’s average temperature has risen by 0.6°C from 1950 to 2010 period of review.
- There is an increasing warming effect due to rising temperatures and a declining precipitation over Zambia with the already drier South-West becoming even drier and affecting the natural systems as well as the agro-ecological regions. The combined or synergistic effect of a rising temperature (warming effect) and reduced precipitation (available water to soils and crops) has direct effect on evapo-transpiration and crop growing season which in this case becomes shorter and leads to low or failed crop yields.
- There is enough reason to warrant a review of the current AER system to bring it in line with the climatic changes to avoid further negative impacts on agriculture.

3.0 Impacts of climate change on agriculture and some implications on health in Zambia

Climate change will have different effects in different regions of the world. Some regions are predicted to have their agriculture productivity increased and recording high yields where as in some areas, agriculture is projected to suffer negative impacts such that yields will significantly drop (Niggol Seo et al., 2008). The critical factors that are climate change related are amounts of carbon dioxide (CO₂), temperatures and rainfall or precipitation. These climatic factors are also limiting agronomic factors whose values and period of time of availability affect plant growth. High CO₂ concentration with high temperatures and high precipitation leads to better plant growth and higher yields (Kurukulasuriya, Rosenthal 2003). However an imbalance of the climatic factors such as increasing temperatures with low rainfall could result in low agriculture productivity via altered plant thermal regimes and growing season. The different impacts will be felt more at global level but will also be felt differently within continents and within countries in different agro-ecological zones. However, there is general agreement that the developing countries in Africa will be hardest hit compared to other countries in other continents.

The IPCC predicts that Africa is the most highly vulnerable to climate change, because of multiple stresses such as changes in both, mean temperatures and rainfall as well as their associated variabilities (IPCC 2007) and the continent’s low adaptive capacity. Rain fed agriculture which characterizes most of Africa, is expected to be negatively impacted by climate change resulting in crops and forage damage and affecting the 16 agro-ecological regions of the continent with varying magnitudes as was demonstrated by the 1992 drought that affected the Southern African Region where losses differed significantly largely due to adaptive capacity. Projections indicate an increase of arid and semiarid lands as is being witnessed in the South-Western regions of Zambia. In some African countries, yield
reductions in rain fed agriculture of up to 50 per cent are projected by 2020. This reduction in agricultural output will ultimately result into food insecurity and exaggerated poverty situation. On average, it is projected that agricultural output in developing countries is expected to decline by 10-20 percent by 2080 (Anderson, Gundel and Vanni 2010) or even as high as 15-30% (FAO 2012). Zambia’s agriculture sector is already experiencing the negative impacts of climate change with a model based prediction that the country’s loss in agriculture GDP could be significantly as high as US$4.3 billion for a ten year period from 2006-2016 (Thurlow et al., 2008).

Agriculture is the cornerstone of livelihoods in Zambia and the Climate Change negative effects will greatly affect the majority of people because agriculture is not only the main source of income for the rural population, especially women, who constitute a high proportion of the rural population and agricultural labour force, but it’s also the major national employer with 85% of the labour force working as subsistence farmers (DFID, 2002) or 90% of them established in informal farming (Central Statistics, 2010). But with the rural poverty levels hovering around 83% (Central Statistics, 2010), any further negative shift due to climate change factors will spell doom to the country in general, but particularly to the rural based populations that entirely depend on agriculture for survival.

3.1 Agriculture Productivity

Climate change will have different effects in different agro-regions of Zambia. As earlier adduced, whereas much of AER II will continue to be highly productive and producing relatively high maize yields, the once acclaimed maize belt in the South of the country (AER I), will continue experiencing low maize yields and less food crop production. Agriculture will continue to be affected in terms of low yields (due to reduced precipitation, increasing warming conditions, increased evapotranspiration, shortened crop growing season due to late onset and early cessation of rainfall, reduced productive lands as some areas become more arid, loss of draught power due to anticipated loss in forage, increase in animal diseases(FAO 2012), change in farming systems as farmers and government switch farming systems to more cash crops and early maturing maize that in itself is not high yielding. The critical factors for agriculture productivity that are climate change related are amounts of carbon dioxide (CO₂), temperatures and rainfall or precipitation. These climatic factors are also limiting agronomic factors whose values and period of time of availability affect plant growth. High CO₂ concentration with high temperatures and high precipitation leads to better plant growth and higher yields (Kurukulasuriya, Rosenthal 2003). However an imbalance of the climatic factors such as increasing temperatures with low rainfall could result in low agriculture productivity because of plant thermal regimes and Length of Growing Period (LGP) factors. The different impacts will be felt differently within Zambia’s agro-ecological zones but with AER I to be more negatively affected compared to other agro-ecological regions.

Therefore the different statistics and projections about agriculture in Zambia have great bearing across the many socio-economic spectrum of Zambia including; national food security, poverty, nutrition and health and the general economic growth indicators such as GDP.
Agricultural productivity in Africa including Zambia is generally low. Taking the case of staple maize that is widely grown in Zambia, the yields per unit area of land are lowest compared to other regions or continents (Gates Foundation 2010, COMESA) and similarly, the national herd for cattle, the major livestock, is only 3,038,000 against 20.3 million hectares of land suitable for grazing (ZNFU, 2011).

Table 1 below, shows consistently lower yields of major crops in Zambia over a 10 years period compared to global averages with the exception of millet.

Table 1 Crop yields (Mt/ha) year, Zambia vs Global Averages

<table>
<thead>
<tr>
<th>Crop</th>
<th>2001/02</th>
<th>2003/04</th>
<th>2005/06</th>
<th>2007/08</th>
<th>2009/10</th>
<th>Global</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>1.1</td>
<td>1.7</td>
<td>1.5</td>
<td>1.3</td>
<td>2.1</td>
<td>4.7</td>
</tr>
<tr>
<td>Sorghum</td>
<td>0.7</td>
<td>0.7</td>
<td>0.5</td>
<td>0.5</td>
<td>0.9</td>
<td>2.66</td>
</tr>
<tr>
<td>Rice</td>
<td>1.0</td>
<td>1.0</td>
<td>1.3</td>
<td>1.2</td>
<td>1.7</td>
<td>3.84</td>
</tr>
<tr>
<td>Millet</td>
<td>0.7</td>
<td>1.0</td>
<td>0.7</td>
<td>1.0</td>
<td>1.1</td>
<td>0.82</td>
</tr>
<tr>
<td>Sunflower</td>
<td>0.4</td>
<td>0.5</td>
<td>0.4</td>
<td>0.5</td>
<td>0.6</td>
<td>-</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>0.4</td>
<td>0.7</td>
<td>0.5</td>
<td>0.6</td>
<td>0.7</td>
<td>1.35</td>
</tr>
<tr>
<td>Soybean</td>
<td>0.7</td>
<td>0.6</td>
<td>0.7</td>
<td>0.7</td>
<td>1.0</td>
<td>-</td>
</tr>
<tr>
<td>Cotton</td>
<td>0.8</td>
<td>1.1</td>
<td>0.9</td>
<td>0.8</td>
<td>1.0</td>
<td>-</td>
</tr>
</tbody>
</table>

*COMESA

Climate change will magnify the low productivity picture and increase the negative statistics unless mitigation or adaptation measures are put in place or adopted. Already, maize which is the most grown crop in Zambia and Africa, has seen yields consistently below global average yields (Table 1) and the need for adoption of such measures is urgent. One proposal by Lipper et al. (2011), is that sub-Saharan African countries should assist smallholder farming systems which support almost 90% of rural populations to transit to more resilient and adaptive agricultural systems.

Continued low maize productivity will lead to national food insecurities that will demand changes in farming systems and practices to fit prevailing conditions and may include increased use of irrigation by commercial and medium farmers. For the majority of small holder farmers, the most likely immediate response may be reducing the farmland sizes for cultivation against the poor available varieties or reducing the livestock herd sizes to try and meet the available limited water resources, rangelands and fodder crops. All these effects will result in further lowered crop and livestock production. That scenario

3 Source: COMESA
will additionally complicate matters of threatened livelihoods. In the context of AERs, the response and conditions entail or call for need to re-visit Zambia’s agro-ecological regions.

Other climate change effects will be those associated with general global warming, which means some regions will experience temperature rises beyond the ideal limits for crop production, natural rangeland production, and animal tolerance. Equally, higher temperatures have been known to induce increased crop evapotranspiration rates which in turn lower the soil moisture levels to below commended levels. The natural environments that support agriculture also provide ecosystems for other life forms of which some of those depend on crops or livestock for their own survival. Some studies on the effects of climate change on these crop/livestock pests have been carried out and the available evidence is that temperature rises are likely to induce much more crop/livestock pests’ physiological survival mechanisms and increase their population dynamics (Gommes and Fresco, 1998; Epstein PR, et al., 1998). Others have focused on the spread of animal diseases and pests from low to mid-latitudes and have shown that change is already under way as evidenced. Bluetongue, for example, a disease affecting mostly sheep, and occasionally goat and deer, would spread from the tropics to mid-latitudes (IPCC, 2007). The consequences of these effects to agriculture will be detrimental: Firstly, high pest/vector population will require much more increased resources and control efforts with conventional methods which are not affordable by the majority of resource poor farmers; Secondly, pest/vector physiological alterations could either mean their easy adaptation to control methods and thereby developing chemical resistance to most introduced products very easily, or vectors shortening the pathogen development cycles and dynamics which could lead to increasing the rates of pathogen transmissions and possibly, increasing the quanta of infective forms of pathogens. It will therefore, require additional government funding into scientific research and development to fully understand these mechanisms in order to manage the control of climate change adapted pests/vectors. The above losses to productive land could be considered as good justification for revision of the AERs but also the urgent need for Government to plan and support adaptation measures to sustain agriculture.

3.2 Agriculture Policy Implications

In October 2004, The Ministry of Agriculture and Cooperatives in Zambia, launched a very comprehensive national Agriculture Policy for the period 2004 to 2015 highlighting the strategies the Government intended to follow in order to increase production and productivity of the agricultural sector and thereby increasing national food security, incomes and reducing poverty (Republic of Zambia, 2004). This was based on the realization that agricultural sector is key to the development of the Zambian economy and it’s anticipated to be the engine of growth. The specific policy objectives are: To ensure national and household food security through an all-year round production and post-harvest management of adequate supplies of basic foodstuffs at competitive costs; To contribute to sustainable industrial development by providing locally produced agro-based raw materials; To increase agricultural exports thereby enhancing the sector’s contribution to the National Balance of Payments; To generate income and employment through increased agriculture production and productivity; and To ensure that the existing agricultural resource base is maintained and improved upon.
Though the policy correctly outlines the need to strengthen emergency preparedness such as droughts, pests, and livestock diseases through early warning information systems and timely crop forecasting, it does not relate these strategies to long term climate change but simply to unstable weather conditions. As such, most of the strategies are those meant to increase agriculture production and productivity in a no climatic change scenario. However, on the basis or using the existing AERs, a few strategies in the policy are highly relevant with respect to climate change adaptation, such as the development and promotion of appropriate seed varieties, planting materials, livestock types and breeds; improved use of available water resources; promotion of sustainable and cost effective agricultural practices; promotion of environmentally friendly farming systems such as conservation farming; and devising efficient and sustainable diagnostic techniques in investigations of diseases of national importance. Even then, with respect to climate change, the above mentioned strategies would be better-off specified like drought resistant seed varieties; promotion of indigenous livestock breeds that are likely to further adapt to more harsh climate change effects; environmentally friendly and sustainable farming systems utilizing indigenous knowledge, etc. In a way, this entails incorporation of climate change adaptation strategies into already existing policies rather than creating separate, self-standing climate change policies which may duplicate others (IISD, 2006). Without incorporation or “mainstreaming” of these strategies into the policy apparatus of governments, sustainability and applicability of climate change adaptation/mitigation to wide scales may not be feasible (Klein, R. 2007).

One good example of an agriculture policy with climate change incorporation is South Africa’s land reform promotion of transferring land from historically wealthy commercial farmers to previously disadvantaged groups. The government’s National Climate Change Response Paper acknowledges that emerging farmers; the recipients under the land reforms, are less resilient to climate change because they are resource poor and constrained in their ability to invest in longer-term planning and as such risks increasing the sector’s vulnerability to climate change (RSA, 2011a). Therefore, the policy adequately distinguishes the need for adequate government funding for resources management, climate monitoring and forecasting, technology development and infrastructure investment, as well as targeted capacity building for farmers with low adaptive potential (Klein, R. 2007).

Since climate change will have diverse and location specific impacts on different regions and countries, it is imperative that each country should prioritize country specific measures (Kurukulasuriya and Rosenthal 2003) that reduce vulnerability, increase adaptation and where it is possible result in mitigation gains (UNGA 2012). It is advised that Zambia climate proof the Agriculture Policy to make it more responsive to effects of climate change.

### 3.3 Socio-Economic Impacts and National GDP

Zambia’s economy is heavily dependent on copper mining which although only contributing 13% of GDP is responsible for almost 80% of Zambia's total export earnings. Agriculture on the other hand contributes 20% of GDP and accounts for more than 60% of labour force. In the rural areas, agriculture is the main employer responsible for almost 87-90% of employment. The majority of farmers almost 98% can be classified as small scale farmers (Neubert et al., 2011) whose agricultural activities are almost 100% dependent on rain. This puts the agriculture sector in Zambia to be extremely vulnerable to rain fall patterns which have become more unpredictable under climate change (NAPA 2007). There is
evidence that the rainfall pattern has direct correlation to Zambia’s agriculture productivity and its contribution to the GDP (Thurlow et al., 2008) and as shown by the World Bank and Central Statistics Office (Figure 3).

Figure 3. Agriculture and National GDP Relationship, 1980-2007

![Agriculture and National GDP Relationship, 1980-2007](image)

4 Slightly adopted from World Bank (2008)

Zambia’s agriculture sector is already experiencing the negative impacts of climate change with severe effects predicted by Climate Change Models showing more frequent extreme events such as droughts and floods in some areas but with a general decreasing precipitation in the Southern parts of the country which will result in shortened crop growing seasons and increased evapotranspiration rates resulting in crop failure or reduced yields of main staple maize crop (NAPA 2007, Ngoma 2010). Using simulation models, Thurlow et al. (2008) have predicted that due to climate change, Zambia’s loss in agriculture GDP could be as high as US$4.3 billion for a ten year period between 2006-2016 or implying that the economy would be 4% smaller by 2016. Kurukulasuriya and Mendelsohn (2008), predict that as a result of climate change, African crop revenues are expected to drop by as much as 14-30% under two different climate change scenarios with the central region of Africa to experience the highest loss in revenues. Following a 1992 drought that hit much of Southern Africa, it was estimated that many countries experienced agriculture crop losses in varying ways. It was estimated that as a result of this drought, Zambia lost US$1.7 billion (equivalent of a 39% drop in agricultural output) and a 2.8 percent decline in the country’s GDP (Chishakwe 2010). What is worth noting is that the same drought resulted in less severe impact on the GDP of South Africa that has a stronger capacity to adapt compared to Zambia depicting variability in impacts on countries with the weaker economies likely to suffer the most (IPCC, 2012; Dixon et al., 2003).
3.3.1 Food Security

Climate change will affect national food security situations due to altered agronomic conditions including; thermal regimes and growing periods that are influenced by temperatures, precipitation and soil properties. These effects will negatively affect Zambia and may contribute to threatening the food security for the country with the poor rural coming worse off.

3.3.2 Reduced cultivatable and range land

Zambia’s population of 14,309,466 has been growing at the rate of 3%. Even though the trend is for people to move to urban areas in search of employment, the farming rural areas have experienced pressure due to the traditional farming systems whereby farmers always look for more fertile and moist land, partly because they don’t use soil conservation practices that should guarantee them longer or even permanent land utilizations. It is expected that the combined synergic effects of continued rising temperatures (Figure 1), declining rainfall pattern (Figure 2) and increasing evapotranspiration (Figure 6), will lead to increased areas becoming more arid and further reducing traditional conventional agro-farming systems resulting in reduced crop yields and livestock populations. These effects will also lead to more intensified land pressures with high potential for conflict and national security. The consequences of this scenario if no corrective measures are taken by government will be reduced cultivatable and range lands against other related factors like poor seeds or inadequate extension services. The noticeable effect will undeniably be even further yield reductions and consequently food insecurity. Therefore, climate change adaptation strategies focusing on increasing yields or grazing efficiency per given land space, need to be urgently formulated and incorporated into the mainstream policies, like observed above.

3.3.3 Livestock losses

By 2020, up to 250 million people in Africa could be exposed to greater risk of water stress due to climate change (UNFCCC, 2007). Reduced precipitation will not only impact crop production, but will also lead to poor range lands for livestock grazing. Rural pastoral farmers will be forced to migrate into areas that have water and pasture. The interface that will be created will be very conducive to diseases transmission, especially from wildlife to livestock as some wildlife populations are known to be carriers of some livestock diseases such as malignant form of Theileriosis in Monze District in 1977/78 (Nambota et al., 1994) and Foot and Mouth Disease (FMD) thought to originate from buffaloes. Other diseases include, anthrax; rabies; rinderpest and trypanosomiasis. The virulent strains are responsible for high livestock mortalities which inevitably change farming systems and AERs.

Livestock farming is an integral part of agriculture and plays a central role in crop production through draught power and organic manure provision, and as a direct source of income. To measure the value of livestock, in Sub Saharan Africa, about 70% (150 million) of the rural poor in Sub Saharan Africa are wholly dependent on livestock to sustain their livelihoods (LID, 1999; AU/IBAR 2002). In Zambia, the largest population of livestock farming is under the traditional sector which is also described as poor resource system (83% cattle, 97% goats, 64% sheep, and 90% pigs). Due to their resource limitations, improvement of this sector has been earnestly hampered.
Among the major constraints to the sector’s improved production and productivity, has been the prevalence of livestock diseases; inadequate grazing; lack of appropriate livestock research and inadequate extension services. The economically important livestock diseases in Zambia are: Tick borne Diseases (Theileriosis, African swine fever, Babesiosis, Anaplasmosis), Trypanosomiasis, Contagious Bovine Pleuro Pneumonia (CBPP), Foot and Mouth Disease (FMD), and New Castle Disease (ND). The prevalence of these diseases and nutrition inadequacies are constraints that will directly or indirectly be magnified by climate change. With continued and anticipated climate extreme events, anticipated expansion of vector-borne and other livestock diseases, range lands will be reduced resulting in reduced income and nutrition quality of the poor rural communities. The majority of livestock in Zambia are of indigenous breeds that have evolved over a long period of time and have adapted well to extreme local environmental conditions like poor feed, endemic diseases, and high temperatures. Even though, Zulu, D.N. (2008), did not establish genetic closeness between our indigenous cattle breeds and the Holstein/Jersey crossbred cattle, the Zambian Livestock Development Plan (2000 – 2004) reported that for the past 30 years, Zambia encouraged the substitution of indigenous breeds and indiscriminate cross breeding of local breeds with exotic ones. The consequences of this selection pressure against indigenous breeds will be the loss of special adaptive characteristics suited for climate change. The sector should be climate proofed in order to minimize effects such as loss of range lands.

3.3.4 Poverty levels due to agriculture failures

Under Comprehensive Africa Agriculture Development Program (CAADP), African governments have adopted agriculture as the main strategy and vehicle that they have agreed to use to attain MDG 1 of halving the proportion of people living on less than a dollar a day and of hungry people by 2015 (Branca et al., 2012). In Zambia, the rural poverty levels for the decade 1990 to 2010, remained very high averaging 83% compared to that of urban areas, 44% (Table 2) and making attainment of MDG1 by 2015 a near impossible target to attain. However, with over 65% of Zambia’s population being rural based (Central Statistics, 2010), agriculture is still the only sustainable vehicle for poverty reduction and food security.

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Rural</td>
<td>88</td>
<td>92</td>
<td>82</td>
<td>83</td>
<td>78</td>
<td>80</td>
<td>78</td>
</tr>
<tr>
<td>Urban</td>
<td>49</td>
<td>45</td>
<td>46</td>
<td>56</td>
<td>53</td>
<td>34</td>
<td>28</td>
</tr>
<tr>
<td>All Zambia</td>
<td>70</td>
<td>74</td>
<td>69</td>
<td>73</td>
<td>68</td>
<td>64</td>
<td>61</td>
</tr>
</tbody>
</table>

\(^5\) Source: Central Statistical Office (2011)
Since it is anticipated that agriculture productivity will be affected differently, across agro-ecological regions, strategic interventions can be guided by poverty levels but also by agro-ecological regions which if climate proofed will be even more effective. Poverty and food insecurity will be magnified under climate change scenario. To realize the full potential of agriculture, government policies including the agriculture policy and the current AER should be climate proofed.

3.4 Health

Although the AERs are not being used in the health sector, it should be acknowledged that human and animal health forms part of the farming systems which are also an important factor in classification of agro-ecological regions. Since climate change will bring about extreme weather events such as droughts, floods, high temperatures, etc. Human health will inevitably be affected in different proportions, directly and indirectly or depending on the vulnerability of the particular population. With respect to Zambia, the largely poor population is expected to be more sensitive to these climate changes because of other compounding factors like nutrition, cross-infections, inadequacy of health facilities and low level of health literacy. The direct impacts will be those associated with weather extremes like unbearable temperatures, humidity and floods. The indirect impacts, and probably more severe, will be those with a bearing on disease epidemiological transmission pathways (vectors and reservoir hosts). Although malaria and nutrition are the focus of this part of the review, other diseases are also discussed.

3.4.1 Rainfall Distribution, AERs Positions and Malaria Prevalence maps

Climate Change will affect distribution of vector-borne diseases such as malaria through altered; vector distribution (McCarthy, et al., 2001), vector reproductive cycles, pathogen reproduction within the vector organism, and prolonged or shortened transmission seasons. Malaria is currently a national health disaster in Zambia accounting for approximately 50,000 deaths annually, and 20% of maternal mortality (Kapelwa, 2001). Under the USCSP (1999), Phiri first correlated malaria distribution in Zambia to rainfall distribution and temperature and observed that other diseases including water borne diseases would also be influenced by climate change (Phiri, 2009). Other studies, like that of Houghton JT, (2001), have similarly established that malaria transmission depends on a combination of temperature and rainfall conditions. Therefore, increase in rainfall and temperature is likely to contribute to increased cases of Malaria.

Studies on prevalence cases of *Plasmodium falciparum* type of malaria shows a national distribution picture with cases more prevalent in the regions III and II as shown in Figure 4 (left) below (adapted from; Riedel et al., (2010). Doted areas on the map indicate estimates of parasite prevalence.
When rainfall distribution map is superimposed onto malaria prevalence, there is a visible match or correlation in areas with high populations. Highest prevalence rate areas are in areas that have rainfall above 1,000mm (AER III) except in NorthWestern and parts of Western provinces which are low populations and in Livingstone area with rainfall below 900mm. The highest prevalence are parts of Copperbelt, Luapula, and Northern (AER III type); Eastern, Kabwe area in Central Province and Lusaka (AER II) and Livingstone (AER I).

### 3.4.2 Malnutrition and stunted growth rates

According to the UN-SG HLP-GS (2012), the number of undernourished people in developing countries increased by about 20 million between 2000 and 2008 with projected demand for food expected to rise by 70% by 2050. This is against a declining agricultural productivity due to many factors but including climate change. The majority of the Zambian population lives in rural areas and depends almost entirely on agriculture for their livelihoods. Zambia has a high percentage of children that are suffering from malnutrition estimated at 45% in 2003-2005 (FAO, 2010) while the Central Statistical Living Conditions Monitoring Survey Report of 2011 indicates a 52% stunting and 16% underweight for children between age 3-59 months from very poor households. Kasali (2008) looking at other nutritional parameters reported stunting levels of 40 – 59% with 51% of the children having had inappropriate diet diversity score. Malnutrition and associated indicators are highest in rural areas with variations among geopolitical boundaries or provinces. It is clear that climate change negative impacts will continue to be felt hardest by the poorest in rural areas that depend on agriculture for their livelihoods.

With a poor performing agriculture as a result of climate change, the number of malnourished children will increase and so will the number of stunted children. A low agriculture productivity will also contribute to an increased disease burden as both the natural immune capacity to fight disease will be compromised and will be worsened by inability to pay for medical bills or even capacity to access medical attention as the poor will not have means to travel to hospitals that are fewer and far away.

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6 Source: Riedel et al. (2010)
from their homes in most cases. Therefore, climate change will exacerbate malnutrition in all age groups but with much more devastating effects on children.

3.4.3 Other human diseases

Although the AERs are not being used in the health sector, it should be acknowledged that human and animal health form part of the farming systems which are also an important factor in classification of agro-ecological regions. Some zoonotic diseases are associated with climatic factors including rainfall. In the mid 1990s, there was an outbreak of bubonic plague in Namwala District in AER II and in 2001, another but more severe outbreak of bubonic plague was reported in Sinda District in Region II. In both districts, the trigger factor was too much rainfall that forced natural hosts to seek drier grounds as their burrows became flooded. This allowed for fleas to feed both on rats and humans to pass on the bubonic plague bacteria. Similar observations may be said of other zoonotic diseases.

3.5 Attainment of Millennium Development Goals (MDGs)

It is not within the scope of this study to review the impact of climate change on the attainment of the MDGs. However, the interest was to show how the impact of climate change on agriculture also impacts on some agriculture related MDGs such as those related to poverty reduction, health, education, environment (which also constitute and characterize AERs), and in general the economic growth of Zambia.

Meeting the 2015 target of MDGs is realistically being seen as still a dream on many fronts. It is accepted that most of the MDGs “targets” will not be met by the year 2015, unless Zambia undertakes significant reforms, investments or acceleration (UNDP, 2011). In many African countries, climate change is likely to be one among many other factors that determine whether the MDGs will be met or not because climate change can easily set back development gains by affecting key sectors such as agriculture, water resources, infrastructures and health (Kandji et al., 2006). As a result of climate change, GDPs in many countries will be negatively affected resulting in slow economic growth or shrinking in economies resulting in resources meant for the social sectors being channeled towards sustaining the economies. Climate change will also have direct impacts on almost all MDGs. As an example, attainment of MDG 1 is almost impossible when food security is not assured. The USAID-GRZ (2011) report observed that Zambia’s performance against the MDGs is a mixed picture and state that of the eight (8) MDGs, the only MGD goal certain to be achieved is MDG2 on; Universal primary education. Other goals pose serious challenges for Zambia as well as donors. However, others would question whether MDG2 can fully be met under climate change scenario considering that climate change induced extremes can directly take children away from school. As an example, extreme climate events such as drought are likely to take children away from school to look for food to support families while floods may direct or indirectly stop children attending school. Poor agricultural yields will contribute to more food insecure families and increased poverty levels. As a result of a combination of food insecurity and increased poverty, many families may not manage to support children to attend school. With respect to human health related MDGs, Kasali (2008), reports that due to extreme poor welfare status of most Zambians, a large gap between the 2015 MDG targets and the existing human health indices exists and despite discrete and sustained improvements in some indicators, it is unlikely that Zambia will meet most of the MDG targets by 2015. It is clear that climate change negatively affects efforts to attain MDGs. Among Zambia’s environmental threats include those that are human induced whose threats are magnified by climate change (USAID-GRZ, 2011). Therefore, it can be summarized that the negative impacts of climate...
change coupled with a declining environmental integrity leads to a declining agriculture productivity that in turn leads to food insecurity thereby exacerbating rural poverty and making the realization of most MDGs an uphill-battle because of the cascading effects that poverty has on other MDGs.

3.6 Major Observations

- Climate change will continue to negatively affect Zambia’s agriculture in all the AERs although differently in terms of magnitude of severity.
- Unless the AERs are revised in line with the observed (present) and projected climate change scenario, Zambia’s agriculture is likely to suffer losses and this will in turn affect the country’s GDP leading to a slowing and in worst case scenario a stagnant economic growth as currently agriculture contributes 20% of national GDP.
- The country’s Agriculture Policy, although not explicitly stated, responds to effects of climate change through the use of AERs to advise farming systems in different AERs. However, AERs related attributes (such as crop suitability rating) should be reviewed as part of the national adaptation strategy.
- Agriculture performance would greatly benefit from a revised AER map for Zambia as this will help with strategic targeting of technical and financial support to the sector

4.0 Agro-Ecological Regions of Zambia

Agro-Ecological Regions (AERs) refer to land areas that are characterized by similarities in terms of weather, climatic conditions, environmental (geophysical, soils), agro-farming systems which include cropping and livestock or animal production systems and services. The classification is therefore based on multiple but almost homogenous factors that are in most cases inter-related and impact on each other. Therefore a discussion of AERs is in effect discussion agriculture in different defined areas that have or are characterized by similar systems influenced by multifaceted factors including; climate, altitude, topography, availability of soil moisture, evapo-transpiration, length of plant growing season, soil classification, cropping, biodiversity and farming systems (FAO, 1999; Mwale et al., 2007; Davendra, 2012). Zambia’s AERs were developed in the 1970’s and early 1980’s and did not incorporate climate change, a phenomenon that will likely affect the AER’s climatological and non-climatological parameters such as farming systems (Niggol Seo et al., 2008) while recent studies in Zimbabwe have shown that climate change has caused a shift in the landscapes of the original AERs (Chikodzi and Mutowo, 2012).

4.1 Agro-Ecological Regions of Zambia

Zambia has three major Agro-Ecological Regions (AERs); Regions I, II and III (Figure 5). These regions are distinguished and classified largely based on climatic, geo-physical, soil types, landuse, some farming systems and socio-economic parameters. Each AER has distinct features such as thermal regimes, rainfall amounts and patterns, length of growing period (LGP), cropping systems, soil types and farming systems including crops and livestock or farm animals and biodiversity. Length of the growing period (LGP) is generally defined as the period in days during the year when the rainfed available soil moisture supply is greater than half the period of potential transpiration (Niggol Seo et al., 2008; Davendra, 2012). Thermal regimes on the other hand are defined by the FAO, as the amount of heat (temperature or degree days) available during the growing period (FAO 1996).
Figure 5 Zambia’s Agro-Ecological Regions and Rainfall (mm) Distribution

![Diagram showing Agro-Ecological Regions and Rainfall Distribution]

The main parameters used in the classification of Zambian AER include, the amount of rainfall, average temperatures, soil types and farming systems (Mwale et al., 2007). For purposes of this report the main parameters guiding this review are rainfall, temperature and soil as these are influenced by and have been used as indicators of climate change but they are also major limiting factors to farming systems. Some of the main AERs characteristics for Zambia are shown in Table 3. Therefore, the argument on whether Zambian AERs should be revised will largely be based on climatological data and in particular rainfall or precipitation, and temperatures and to a lesser extent, soil characteristics.

Table 3. Zambia Agro-Ecological Regions (AERs) Main Features

<table>
<thead>
<tr>
<th>AER #</th>
<th>Average Annual Rainfall (mm)</th>
<th>Average Maximum Temperatures</th>
<th>Average Minimum Temperatures</th>
<th>Plant Growing Period (days)</th>
<th>Main Farming System and soil Characteristics</th>
<th>Geographical Expanse covered</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>400-750</td>
<td>36-37</td>
<td>9-14</td>
<td>60-90</td>
<td>Mixed Crop and livestock, Early maturing varieties encouraged, some large commercial irrigation. Dry eroded soils</td>
<td>South-Western and Western parts of the Eastern Zambia following the Zambezi-Luangwa Valleys (20% land area)</td>
</tr>
<tr>
<td>IIa1</td>
<td>750-1,000</td>
<td>30-32.5</td>
<td>5-8</td>
<td>90-150</td>
<td>Limited mixed farming. Flood plains</td>
<td>Central band</td>
</tr>
</tbody>
</table>

Source: Thurlow et al. (2008).
4.1.1 Agro-Ecological Region I

The region’s average annual rainfall range is 400-750mm and average temperatures of 30-36°C. The region has diverse and slightly acidic and eroded soil types that are frequently exposed to climatic events such as droughts and flash floods. Due to precipitation or moisture stress and short plant growing season of 60-90 days, the region is characterized by drought tolerant and early maturing subsistence mixed cropping systems. The Southern parts along the Zambezi River valley have commercial irrigation farms for cash crops. This is the driest region but recent observations suggest that in the northern parts of this region (in the Eastern Province), the amount of rainfall could have shifted to ranges similar to Region II (Figure 6). This justifies a review of the AER to determine the geographical and climatological parameters.

8 Slightly adapted from: (Mwale et al., 2007)
4.1.2 Agro-ecological Region II

The region’s average annual rainfall range is 750-1000mm and average temperatures of 30-32°C. However, recent rainfall maps (Figure 6), show that some parts of the Eastern Province appear to be receiving higher than the current designated average rainfall almost in the ranges of 1,000-1200mm as in the Region III. The region has the most fertile soils and has good plant growing season range of 90-150 days which is good and capable of supporting growth of almost all crops grown in Zambia. However the use of fertilizers is causing some localized acidification of soil. Much of the country’s agriculture is this region and comprises both mixed cropping subsistence to commercial farming. Apart from climatic parameters used in classification, soil type is also very important because the region shows a diversity of soils with the Central-Eastern (Region IIa) being the most fertile but giving way to less fertile and water logged Kalahari soil types in the Western regions.

4.1.3 Agro-ecological Region III

This is the largest AER covering 50% of Zambia’s land area and average annual rainfall of 1,200-1,500mm and average temperatures of 30-33°C with extreme northern parts receiving annual average rainfall above this range. The effects of heavy rainfall are evident in the soil type which is highly leached. The region has the longest plant growing season of 140-200 days. The farming systems are predominantly mixed crop subsistence but there is an observed migration from the drier AERs to this wetter region and commercial agriculture is being promoted. Moisture in this area is generally not a limiting factor to agriculture.

4.2 The use of Agro-Ecological Regions as a Climate Change Adaptation Strategy

The AERs have been used in Zambia for policy and as adaptive management tool in agriculture since the late 1970’s. The AERs have strategically been used to guide government policy on how to support agriculture in different geographical and climatic regions of the country. Its development did not incorporate climate change science as presently understood and, therefore, its effectiveness under a changing climate has been challenged. In Zimbabwe a recent study has proposed a revision of the AER in Masvingo because, the existing AERs developed in the 1960s have their effectiveness reduced due to climate change (Chikodzi and Mutowo, 2012).

Farming systems are practiced generally to suit an AER. This is evident in the Zambian AER where certain crops or livestock systems are more associated with low rainfall areas and the same is true of the higher rainfall areas whose farming systems are characterized in the case of crops by those crops that have a long growing season and in some cases characterized by two planting schedules within one season as the case is with beans in the Northern Region in AER III. AERs classification has been used as a key policy as well as an adaptive management tool in Zambia’s agriculture sector. Among the uses include;

- Guiding agro-climatic and farming systems including cropping systems most suitable to each of the three AERs
- Guiding extension services and especially advising farmers on farming systems
- Guiding investments in the country’s investment promotion and support such as the Farmer Input Support Programme where government supplies mainly maize seed (suitable to an AER) and fertilizer inputs to small scale farmers at a subsidized price
- Guiding strategic localized as well as national agro-scientific research such as development of crop varieties that are most suitable to different AERs
Disaster management planning especially in times of extreme events such as droughts and floods that impact AERs differently. The AERs have so far served their purpose over the past three decades. However, it is also true that due to the climate change, the AERs do not have the same characteristics they had thirty years ago as it has been shown by several studies that some critical climatic parameters have in fact changed and continue to change.

4.3 Effectiveness of the Current AERs

Zambia’s AERs have been used to guide both government policy as well cross-sections of farmers on types of crop suitability based on the AERs. Since the 1970’s when the tool was developed, direct use include influencing research into suitable crop varieties for different regions, the development of crops with different agronomical requirements such as early, medium and late maturing varieties as would best suit an AER. The current data suggests that climatological parameters that were used in the zoning of Zambia’s AER are changing across the different AERs as shown for temperatures (Figure 1 and 2) and for rainfall (Figure 3). Temperatures are steadily rising while rainfall is gradually decreasing. However, in some areas of current AER zoning, some parts are getting wetter while others are getting drier (Figure 6). This observation is similar to the observations of Chikodzi and Mutowo (2012) in Masvingo AERs in Zimbabwe. The changes in key climatological parameters in different AERs are consistent with many model projections by many scientists that climate change would impact AERs but in varying ways and magnitude. Therefore, although the current AERs landscape zoning is still useful, it may not be as effective for supporting policy as well as be used as an effective adaptation tool in agriculture. It is therefore, recommended that the AERs be revised to reflect current and future scenarios under climate change.

4.3.1 Baseline scenario

4.3.1.1 Climatological

Zambia’s classification of the three agro-ecological regions is based on soil types, rainfall and other climatic conditions (Mwale et al., 2007). Since the creation of the AERs, there has been a review of climatic parameters but not the soils. The agro-ecological regions classification for Zambia was completed in the early 1980’s. The climatological data that was used in the zoning of Zambia’s AER are changing across the different AERs as shown for temperatures (Figure 1 and 2) and for rainfall (Figure 3). Temperatures are steadily rising while rainfall is gradually decreasing. However, in some areas of current AER zoning, some parts are getting wetter while others are getting drier (Figure 6). This observation is similar to the observations of Chikodzi and Mutowo (2012) in Masvingo AERs in Zimbabwe. The changes in key climatological parameters in different AERs are consistent with many model projections by many scientists that climate change would impact AERs but in varying ways and magnitude. Therefore, although the current AERs landscape zoning is still useful, it may not be as effective for supporting policy as well as be used as an effective adaptation tool in agriculture. It is therefore, recommended that the AERs be revised to reflect current and future scenarios under climate change.

4.3.1.2 Soils

The soil suitability for major staple and cash crops assessments was developed based on the application of the FAO land evaluation system modified for Zambian conditions (Mwale et al 2007). For each AER, suitable and recommended crops are listed and mapped.

Although most of the morphological and physical features of Zambia’s plateau soils, are similar across the country, the effects of climate have made their chemical properties and distribution different (Mwale et al., 2007). This implies that climate change exerts influence on soil physic-chemical properties over time and monitoring of these changes just as climatological variables are monitored is advisable in understanding the integrity of AERs. Although soils and parent rock “out-crops” in some AERs show
resilience to effects of rainfall, some soils especially in AER I are easily eroded by effects of weather as well as human induced stress. The possible increased rainfall in areas of AER II in parts of Eastern Province could pose serious erosion to this sensitive but fertile soil that would also suffer effects of leaching.

4.3.1.3 Crop suitability and farming systems

The observed increasing average temperatures, reducing rainfall and the possible degradation of soil under climate change (Mwale et al., 2007) has serious implications for agriculture productivity because of the impact these climatic and environmental factors have on water availability and evapotranspiration which are key to the Length of Growing Period (LGP) in agriculture (FAO, 1996; Thurlow et al., 2008). The LGP is the period of the year when suitable environmental conditions (moisture and temperatures) are attained. Devendra (2012) defines the LGP, as the period in days during the year when the rain fed available soil moisture supply is greater than half the period potential transpiration. Crops grown in an AER must ideally mature within the LGP to attain maximum yields. The suitability crops system takes into account LGP, thermal regimes to ensure highest possible crop yields. On the basis of the data on changing climatic parameters for the past three decades, it is advisable that crop suitability maps should be revised and research into development of suitable cultivars be strengthened.

4.3.2 Climate Change Scenario

The Southern African region including Zambia has experienced signs of climate change especially in the recent past decades where extreme events such as droughts and floods and their severity have occurred more frequent than usual compared to past similar length of periods as has been observed by several studies. According to recent studies, climate change influenced trends have been observed and the trends include; changes in the start of rainy seasons, increased or decreased average precipitation and increasing average and maximum temperatures (Ziervogel et al., 2008). A similar trend has also been observed in Zambia (NAPA, 2007; Ngoma, 2010) where the start of the rainy season has changed generally tending towards late start and early ending resulting in shortened crop growing season. As a result of some observed shifts in rainfall patterns and the increasing temperatures, questions have arisen about the effectiveness and current geographical boundaries of Zambia’s Agro-Ecological Regions. There have been suggestions that the current AERs geographical boundaries and climatological characteristics could have in fact changed (Neubert et al., 2011).

According to the data provided by the Zambia Meteorology Department (ZMD 2013), the three (3) climatological normals since 1950 to 2010 show a reduction trend in amounts of rainfall and increasing temperatures across all the agro-ecological regions. A similar trend has been reported for the period 1970-2000 (NAPA, 2007). This trend could mean that some variable parameters (climatic, geological, soils, agro-climatic and farming systems) that were used in the zoning of Zambia’s agro-ecological regions could have changed. Anecdotal evidence being the observation that some farming systems have tended to shift northwards to the wetter agro-ecological region III which has highly leached and acidic soils and therefore less suitable and less fertile for crop production compared to the most agricultural productive areas of much of the Southern and some parts of Eastern Zambia in agro-regions I and II. This observation is consistent with Kurukulasuriya and Mendelsohn (2008), who observed that the greatest harm from climate change is that it will shift farms from high to low productive Agro-Ecological Zones (AEZs). Therefore, it is inferred here that climate change is influencing and changing the characteristics of AERs over time and that it is necessary on this basis that AERs are reviewed accordingly over a set time period depending on established speed of change of key parameters.
Rainfall has generally decreased and shows a decline across the country (Figure 6). Over all, rainfall has been decreasing faster in AER III than other two regions with some parts of region II (parts of Eastern Province) having become wetter than they were in 1970 base year. Whereas region I has received less rain in the SouthWestern region of the country, it has received more rain in the North East. There is a downward gradient of annual rainfall from the north to the south of the country, with the highest rainfall in the northwest and northeast (generally above 1200 mm) and the lowest in the southwest (generally below 800 mm) Thurlow et al., (2008). It can be said with a degree of confidence that conditions in some AERs have changed since the 1970s baselines to warrant revisions.

As a short term measure, eco-based agriculture practices should be promoted in areas whose key AER features have changed to compensate for the negative effects that would affect crop growth and productivity.

4.3 Major Observations

- General the AERs have proved very useful to agriculture development in Zambia. The tool has influenced policy on agriculture, land use and agriculture productivity.
- As a result of climate change, some key climatologic parameters that were used in the development of Zambia’s AERs have changed. This could mean that the current AERs map for the country may have shifted and changed. This could justify the need to undertake a review of

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the status of the current AERs. As part of long term planning, the review of AERs could also be done over a set period of time such as following climatologic normals.

- The use of the AERs in health sector is not very clear and requires more specific and detailed studies to establish any link.

### 5.0 Recommendations

i. In order to reverse the country’s loss in agriculture GDP and national GDP, as a result of climate change, Zambia should climate proof policies including the Agriculture Policy and the Agro-Ecological Regions Map,

ii. In view of the fact that parameters that were used to develop AERs have changed over the past three decades, it is recommended that Zambia reviews the current AERs to respond to the present and future projected conditions imposed by climate change. As part of the review, it is advisable that crop suitability maps should be revised and research into development of suitable cultivars be strengthened,

iii. Zambia should identify and prioritize adaptation and vulnerability reduction measures and promote agro-production systems that offer resilience to climate change, increase crop yields per hectare and where possible add mitigation benefits,

iv. As a long term measure, the Government should support and or develop programmes and measures that sustain improved socio-economic status of those AERs (especially regions I and II that are becoming less productive) in order to stem “drier-wetter” environmental migration that could become future source of serious internal conflict and security risk,

v. The country should strengthen and or build capacity for scientific research institutions involved in agriculture with allocation of reasonable resources including human, technology and financial, and;

vi. Climate change induced collapse of agriculture has direct and indirect impacts on health. It is recommended that a study be done to assess the impact of climate change, agriculture and health in a high rural, high poverty but highly productive agricultural province such as the Eastern Province.
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ANNEX 1

Project Output 2

PROJECT CONCEPT:

THE REVISION AND CLIMATE CHANGE PROOFING OF ZAMBIAN AGRO-ECOLOGICAL REGIONS

1.0 Title of Project

To Revise and Climate Change Proof the Zambian Agro-Ecological Regions (AERs) in order to promote a sustainable agricultural sector in Zambia.

2.0 Summary of the Project

The impacts of climate change on Zambia’s economic and social services sector have been elucidated by many authorities and institutions including the Zambia Academy of Sciences (ZaAS). The Zambian National Adaptation Plan of Action (NAPA) of 2007 assessed impacts and in some cases proposed possible adaptation programs or activities. The review of the impacts of climate change on Agro-Ecological Regions (AERs) zones or maps undertaken by the ZaAS and studies by other institutions, have suggested that the AERs of Zambia could have shifted. The shifting of AERs has serious implications for the agriculture and health sector as well as for the national GDP which has been shown to be strongly linked to agriculture GDP. Although suggestions have been made to the effect that AERs could have shifted, this has not been established by actual ground work. It is necessary to undertake field work in some selected locations in the different AERs of Zambia. This will be done through studies on climatological parameters, soil characteristics and types of agro-ecological farming systems in representative loci in the three AERs of Zambia. The project will also support the technical and administrative capacities of collaborating institutions to undertake climate change impacts assessment and adaptation strategies. The Zambia Academy of Sciences will commission this study and make necessary policy recommendations to Government to undertake a similar study but covering all district (political and geophysical) boundaries of Zambia.

3.0 Key words: Agro-Ecological Regions, Climate Change, Climatological Parameters, Pilot Districts

4.0 Proposed Start Date and Duration: October, 2013- September 2016 (thirty six months).

Applicant: Zambia Academy of Sciences, at; National Institute for Industrial and Scientific Research (NISIR), P O Box 310158, LUSAKA 15302, Zambia

Email: zaas@iconnect.zm; zambiaacademysciences@gmail.com

Contact Person and Project Coordinator: James S Phiri; Email: jamessphiri@gmail.com
5.0 Collaborating Institutions

The key collaborating institutions include;

i. The Zambia Academy of Sciences (ZaAS)
ii. The Institute for Eco-Development Strategies and Toxicology (IESTO), Lusaka, Zambia
iii. The University of Zambia (UNZA), School of Agricultural Sciences, Lusaka, Zambia
iv. National Institute for Scientific and Industrial Research (NISIR), Lusaka, Zambia
v. The Zambia Agriculture Research Institute (ZARI), of the Ministry of Agriculture and Livestock (MAL), Lusaka, Zambia
vi. The Zambia Meteorology Department of the Ministry of Transport and Works, Lusaka, Zambia

6.0 Background and Justification

The Zambia Academy of Sciences (ZaAS) with the financial support of NASAC and the Germany Academy of Sciences, Leopoldina, has undertaken a review of the impact of climate change on Zambian Agro-Ecological Regions (AERs). The review of the impacts of climate change on AERs zones or maps undertaken by the ZaAS and studies by other institutions, have suggested that the AERs of Zambia could have shifted although no study has quantitatively verified these observations.

Agro-Ecological Regions refer to land areas that are characterized by similarities in terms of climatic conditions, environmental (geophysical, soils), agro-farming systems which includes cropping and livestock or animal production systems and services. The classification is based on multiple but almost homogenous factors that are in most cases inter-related and impact on each other. Zambia's AERs were developed in the 1970’s and early 1980’s and did not incorporate climate change and therefore calls into question its effectiveness as a policy and adaptive management tool.

This project to “Revise and climate proof AERs of Zambia”, is developed from some recommendations and observations from the just concluded review work by ZaAS. It will build on the previous work by undertaking field work in three selected field locations in the three different agro-ecological regions on a pilot basis. The project will also support the technical and administrative capacities of collaborating institutions to undertake climate change impacts assessment and adaptation strategies.

The Zambia Academy of Sciences will commission this study and make necessary policy recommendations to Government to undertake a similar study but covering all district (political and geophysical) boundaries of Zambia.

a) Project Purpose

The purpose of the project is to revise and climate proof AERs of Zambia. This will be done through the assessment and establishment of the extent to which the AERs have been affected and shifted by climate change. The project will also support and strengthen the capacity of collaborating institutions in Zambia.

b) Project Objectives

The Project Objectives are to;
i. Assess and establish the extent to which the AERs have been affected and shifted by climate change
ii. Document or establish and climate change proof the AERs and the agro-ecological farming systems in representative loci in the three AERs of Zambia
iii. Targeted strengthening of the institutional and technical capacity of the collaborating partner institutions
c) Expected Outputs/Outcomes

The expected Project Outputs or Outcomes are;

i. The extent of the shift in AERs is established.
ii. AERs and agro-ecological farming systems described and climate change proofed.
iii. Appropriate adaptation and vulnerability reduction measures and strategies that offer resilience to climate change, increase crop yields per hectare and add mitigation benefits identified prioritized and promoted according to agro-climatological production systems.
iv. Strategic strengthening of technical and administrative capacities of collaborating institutions undertaken by the end of project.
d) Project Justification

This project will be a pilot project and basis for Zambia to revise her Agro-ecological regions classification. The project further helps to strengthen ZaAS position as a science advisory body and influence Government policies on science and agriculture in particular. In the long term, the project helps raise the visibility of the ZaAS both at national, regional and international level.

7.0 Project Time Frame

The Project will be implemented over a period of 36 months.

Table 4 Project Implementation and deliverables

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<td>Appointment of Assistant Project Coordinator</td>
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<td>Project Mid-Term Review</td>
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<td>Project Completion Report Submitted to ZaAS Executive Committee</td>
<td>Preparation of project report by core team and peer reviewed</td>
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8.0 **Project Budget**

The estimated budget for the three years is $1.5m (say One Million Five Hundred Thousand Dollars USA).

9.0 **Possible Funding Sources**

ZaAS and the collaborating partner institutions seek the financial and technical support of different funding partners and especially those through the NASAC and the Inter-Academy Panel (IAP) as well as through bilateral agencies in Zambia or multilateral agencies.
ANNEX 2

Project Output 3

Terms of References for Long term Study on Climate Change Proofing of the Agro-Ecological Regions (AERs) of Zambia

The Terms of References (TORs) for the long term project will be derived and developed from the Project proposal (Annex 1) and from Major Observations and Recommendations from the previously just completed ZaAS Review Document (Adaptation of Zambian Agriculture and Health Programs to Climate Change- A Comprehensive Review of the Agro-Ecological Regions). Both the Major Observations and Recommendations from the recent concluded Project are reproduced here-below;

A) Major Observations from the ZaAS Review Document

- Due to changes to climatologic parameters, Zambia’s agro-ecological systems are likely to have changed or shifted but a more detailed study should be undertaken to confirm the changes and thereby revise the AERs map of Zambia.
- Unless the AERs are revised in line with the observed (present) and projected climate change scenario, Zambia’s agriculture is likely to suffer losses and this will in turn affect the country’s GDP leading to a slowing and in worst case scenario a stagnant economic growth as currently agriculture contributes 20% of national GDP.
- The use of the AERs in health sector is not very clear and requires more specific and detailed studies to establish any link.
- The current AERs landscape zoning is still useful. However, as a result of climate change, some parameters that were used in zoning three decades ago, have changed and these include; declining rainfall gradient across the country, increased average temperatures and increased evapotranspiration (where it is getting higher in the Southwest regions of the country). Therefore, the AER as a tool may not be as effective for supporting policy and adaptation in agriculture. It is therefore recommended that the AERs be revised to reflect current and future scenarios under climate change.

B) Recommendations from the ZaAS Review Document

Zambian agriculture is highly vulnerable to climate change and yields will continue to be low unless policy measures are climate proofed. As a result of climate change, the country’s loss in agriculture GDP is approximately US$430 million per year. Zambia should climate proof policies including the Agro-Ecological Regions Map. Therefore, it is recommended that;

vii. In order to reverse the country’s loss in agriculture GDP and national GDP, as a result of climate change, Zambia should climate proof policies including the Agriculture Policy and the Agro-Ecological Regions Map,

viii. In view of the fact that parameters that were used to develop AERs have changed over the past three decades, it is recommended that Zambia reviews the current AERs to respond to the
present and future projected conditions imposed by climate change. As part of the review, it is advisable that crop suitability maps should be revised and research into development of suitable cultivars be strengthened,

ix. Zambia should identify and prioritize adaptation and vulnerability reduction measures and promote agro-production systems that offer resilience to climate change, increase crop yields per hectare and where possible add mitigation benefits,

x. As a long term measure, the Government should support and or develop programmes and measures that sustain improved socio-economic status of those AERs (especially regions I and II that are becoming less productive) in order to stem “drier-wetter” environmental migration that could become future source of serious internal conflict and security risk,

xi. The country should strengthen and or build capacity for scientific research institutions involved in agriculture with allocation of reasonable resources including human, technology and financial, and;

xii. Climate change induced collapse of agriculture has direct and indirect impacts on health. It is recommended that a study be done to assess the impact of climate change, agriculture and health in a high rural, high poverty but highly productive agricultural province such as the Eastern Province.