Working Paper

AfricaInteract: Enabling research-to-policy dialogue for adaptation to climate change in Africa

Review of Research and Policies for Climate Change Adaptation in the Agriculture Sector in Southern Africa

Paul Mapfumo[1], Abdulai Jalloh[2] and Sepo Hachigonta[3]

July 2014

Acknowledgement

This review was undertaken under the auspices of the AfricaInteract project funded by the International Development Research Centre (IDRC).

This paper has been edited by Abdulai Jalloh, Aboubakar Njoya and Harold Roy-Macauley; and reviewed by Amos Majule and Lars Otto Naess

Authors' Affiliations

[1] **Professor,** Department of Soil Science & Agricultural Engineering;,and Soil Fertility Consortium for Southern Africa (SOFECSA) Regional Coordinator, University of Zimbabwe, P.O. Box MP167, Mt Pleasat, Harare, Zimbabwe.

[2] **Programme Manager,** Natural Resources Management Programme, Conseil Ouest et Centre Africain pour la Recherche et le Développement Agricoles/West and Central African Council for Agricultural Research and Development (CORAF/WECARD), 7 Avenue Bourguiba, BP 48, cp 18523 Dakar, Senegal.

[3] **Climate Change Programme Manager,** Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN), 141 Cresswell Street, Weavind Park 0184, Pretoria, South Africa; Postal address: Private Bag X813, Silverton 0127, Pretoria, South Africa.

About *AfricaInteract*

AfricaInteract (http://africainteract.coraf.org/en/) is a platform enabling research-to-policy dialogue for adaptation to climate change among a broad range of African stakeholders in sub-Saharan Africa. These include civil society, researchers, policy-makers, donors, and the private sector working on adaptation to climate change in the agriculture and health sectors as well as urban areas with water and gender as cross cutting issues. The overall objective of AfricaInteract is to develop a platform for the effective and efficient transfer of information to policy makers, with the ultimate aim of enhancing the resilience of vulnerable populations.

AfricaInteract is funded by the International Development Research Centre (IDRC) and coordinated by the West and Central African Council for Agricultural Research and Development (CORAF/WECARD) under the auspices of the Forum for Agricultural Research in Africa (FARA). The regional focus of *AfricaInteract* is based on the Regional Economic Communities in the four sub regions of sub-Saharan Africa. Focal organizations coordinating regional activities are as follows: The Association for Strengthening Agricultural Research in East and Central Africa (ASARECA) – East Africa; Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN) – Southern Africa; Commission des Forets d'Afrique Centrale (COMIFAC) – Central Africa; and Energie-Environnement et Developpment (Enda) – West Africa.

The West and Central African Council for Agricultural Research and Development (CORAF/WECARD) is a constituent of the Forum for Agricultural Research in Africa, and comprising 22 National Agricultural Research Systems in West and Central Africa. CORAF/WECARD's mission is "Sustainable improvements to the competitiveness, productivity and markets of the agricultural system in West and Central Africa by meeting the key demands of the sub-regional research system as expressed by target groups" with strong alignment and commitment to the overall goal of the Comprehensive Africa Agriculture Development Programme of the New Partnership for Africa's Development. www.coraf.org

Table of Contents

Acronyms and Abbreviations

ACT	African Conservation Tillage Network
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
ASWAp	Agriculture Sector Wide Approach of the Government of Malawi
CA	Conservation Agriculture
CAADP	Comprehensive Africa Agriculture Development Programme
CCAA	Climate Change Adaptation in Africa
COMESA	Common Market for Eastern and Southern Africa
DFID	Department for International Development
FANRPAN	Food, Agriculture and Natural Resources Policy Analysis Network
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross domestic product
GEF	Global Environment Facility
HIV/AIDS	Human immunodeficiency virus / acquired immunodeficiency syndrome
IDRC	International Development Research Centre
IIED	International Institute for Environment and Development
ISFM	Integrated Soil Fertility Management
NAPA	National Adaptation Programme of Action
NEPAD	New Partnership for Africa's Development
NGO	Non-governmental organisation
PAR	Participatory action research
SADC	Southern African Development Community
SOFECSA	Soil Fertility Consortium for Southern Africa
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
WWF	World Wide Fund for Nature
ZERO	Zimbabwe Regional Environment Organization

Executive Summary

There is a growing and critical need for decision-makers at different levels in Africa, from local (community) to national and sub-regional scales, to develop matching response strategies and policies in order to reduce vulnerability and foster resilient livelihood systems on a sustainable basis. This document presents the main findings of a critical review conducted to examine the current evidence of research and policies on climate change adaptation in the agricultural sector in Southern Africa.

The review was commissioned under the AfricaInteract project, funded by the International Development Research Centre (IDRC) and coordinated by the West and Central African Council for Agricultural Research and Development (CORAF/WECARD). With a specific focus on Malawi, South Africa and Zimbabwe, the desktop review was guided by three main objectives: i) to synthesise the major findings from agricultural research on climate change adaptation conducted in Southern Africa; ii) to identify research and policy gaps on climate change adaptation with a specific focus on Southern Africa's agricultural sector; and iii) to identify key stakeholders and opportunities for climate change adaptation for the agricultural sector in Southern Africa. For the purposes of the study, agriculture was defined broadly to include not only crops and livestock, but also forestry and fisheries systems. Information was primarily drawn from available but limited refereed journal articles, official government documents and grey literature from reports and websites of diverse organisations practically addressing or actively engaged in debate on climate change issues in the Southern African region.

Drawing from Intergovernmental Panel on Climate Change (IPCC) definitions, the review first explores the concepts and understanding of adaptation, resilience and coping in the context of climate change. The study shows that Southern Africa is experiencing increasing climatic pressures in the agricultural sector, for which matching policies to support adaptation responses are urgently required. The sector supports 60-90% of national populations, who draw their livelihoods directly from climate-sensitive crop, livestock, forestry and fisheries systems. The region's agriculture is dominated by smallholder farming, which contributes 60-66 percent of total production in countries such as Malawi and Zimbabwe. For example, smallholder farmers in Zimbabwe own about 80 percent of the national livestock herd. In South Africa, smallholder agriculture has traditionally received very little attention in national development policies. However, this has changed following a realisation of the sub-sector's critical role in reducing vulnerability of rural communities to food insecurity as well as its potential to lessen the fiscal burden in rural development. It is clear that agriculture will continue to underpin major economic activities for regional countries, providing for food security, national employment and foreign exchange earnings into the foreseeable future. However, low and variable growth performance of the sector, against a growing farm-based population, raises major development concerns in the face of climate change. Major sources of climatic pressures in agriculture include increasing temperatures, shortening growing seasons and deteriorating rainfall distribution within seasons, as well as increasing frequencies of droughts. The region's predominantly rain-fed agricultural sector traditionally suffers from lack of access to appropriate information, knowledge and improved production and processing technologies by different farmer categories. These multiple constraints may greatly limit the scope for climate change adaptation.

The available evidence indicates that smallholder farming communities are inherently the most vulnerable to the pending negative impacts of climate change, and are also less likely able to take advantage of any emerging opportunities due to resource constraints. The region's smallholder agriculture hinges on rain-fed maize-based cropping systems, with sorghum and millets (collectively termed small grains) being prominent in drier agro-ecologies (less than 600 mm rainfall annually). Over 65 percent of current national agricultural earnings are derived from the crop production sub-sector, for which there is emerging evidence of risks from increased climate variability and change in breadbasket agro-ecologies. Based on current evidence, areas suitable for production of these staples cereals, particularly maize, are projected to shrink by 5-25 percent, and yet the region is already known to be chronically food insecure. Expansion in cropped area therefore explains much of the witnessed contributions of smallholders to national crop production. These challenges are aggravated by diminishing soil productivity and a decline in the natural resource base that has, hitherto, supported the poorer sections of rural and peri-urban communities. Productivity is critically low (e.g. under 0.8t/ha for maize) due to poor and declining fertility against low levels of external inputs use by farmers (e.g. fertiliser and improved seed). National governments have long struggled to develop effective agricultural policies that overcome the multiple constraints faced by farming communities, and current evidence suggest that climate change will present an extra load of challenges in the formulation of responsive development policy frameworks for sustainable intensification and diversification of current farming systems.

Analysis of documented evidence on climate change adaptation indicates that communities have drawn on indigenous knowledge systems, the strength of local institutions and traditional social safety nets to adapting to multiple stress factors including climate variability and change. However, there is limited empirical evidence on the robustness of these systems in supporting new forms of social collaborations and resolving conflicts arising from resource scarcity in the wake of climate change. Most of the farmers' current responses to climatic shocks have been of a short-term nature, and often punctuated by external but temporal response measures such as food aid/relief programmes. Climate change impacts are likely to have ramifications beyond agriculture by influencing major areas of development that include: i) dynamics of rural-urban interconnections; ii) access and use patterns for major natural resource pools such as land, water and forests; iii) resource governance and social safety net systems within/across communities; iv) access to marketing and trading opportunities; and v) redefined approaches for addressing HIV/AIDS, among other diseases, in agriculture. Comprehensive policy frameworks are therefore required to expand climate change adaptation horizons beyond the boundaries of current farming systems. For example, as the risk of crop-based enterprises increase with deteriorating climatic conditions, there is evidence of farmers adapting through diversification into livestock. However, that sub-sector is also threatened by non-availability of feed resources, low animal productivity performance, emerging livestock pests/diseases, increasing water scarcity and heat stress.

There was evidence of multiple stresses characterising existing poverty traps for the predominantly rural communities, and challenges of chronic food insecurity. However, there is no evidence on how current agriculture and climate change policy frameworks are able to address these multiple stress factors against the increasing risk and uncertainty of agriculture as a source of climate change adaptation. There is evidence of a clear convergence of opinion from researchers, national and regional policymakers and farmers on the need to transform Southern Africa's current agricultural systems in the face of climate change. Currently, the majority of farmers live beyond the reach of markets, yet agricultural development policies are hinged on principles of (assumed) market participation. Transformation of these subsistence farms into commercially oriented and market-driven production systems will effectively call for structural and process changes in knowledge systems, technology development and delivery, institutions and policies.

The review also revealed a dearth of empirical research evidence on current and future impacts of climate change and variability on agricultural production systems, and their implications on resilience of smallholder farming systems currently supporting the poorer and more vulnerable communities. Notably, there were indications of an increase in awareness about climate change issues by diverse stakeholders, including policymakers, over the past decade. However, lack of empirical evidence on the nature, magnitude and direction of impacts at local (community) and national scales will likely continue to haunt decision-making processes towards development of robust strategies and policies to support adaptation. There are also some knowledge gaps, and in some cases conflicting views in the grounding of theories, methodologies and knowledge applications by practitioners that are meant to inform decision-making processes. This may explain the current lack of clear policies on climate change adaptation in the agricultural sector in almost all regional countries including South Africa. There is an apparent disconnect between policy processes and realities at the grassroots, and therefore there is a general lack of consistency between the policies and technical interventions in the implementation plans. For example, the strong policy assertions in support of adaptation options such as development of irrigation and crop-livestock systems is not supported by calls for establishment of irrigation training institutions; crop and national livestock improvement centres; and/or fertiliser development institutions. One can therefore conclude that current national climate change policies represent steps in the right direction, but tend to be 'business as usual' and offer limited scope for implementation of appropriate adaptation options. The region's agricultural sector will need to undergo major transformation processes in order to meet emerging demands for adaptation. This may entail changes in the types and forms of information, knowledge, technologies, resource regimes and institutions driving current production systems. There are still major knowledge gaps across disciplines on how local level changes in climatic factors (e.g. rainfall, temperature, humidity and air circulation patterns) influence the socio-ecological processes that underpin agricultural production systems across spatial and temporal scales.

One of the major conclusions of the study is that policymaking on climate change in Southern Africa is not necessarily constrained by lack of empirical evidence, but instead by the failure of policymakers to use available empirical evidence. This suggest that current failures in linking research to policy could be a major barrier to further research and development innovations for climate change adaptation. Evidence from limited climate change adaptation studies conducted with communities in the region revealed the importance of policy dialogue platforms as an integral part of research and development initiatives. Coupling of participatory action research (PAR), co-learning and innovation system approaches, involving communities, farmer organisations, public and private research and extension and policymakers among other stakeholders proved effective in linking research to policy.

1. Introduction

1.1 Background and motivation

This document presents the main findings of a critical review of research and policies on climate change adaptation in the agricultural sector in Southern Africa. The review was commissioned under the AfricaInteract project, funded by the International Development Research Centre (IDRC) and coordinated by the West and Central African Council for Agricultural Research and Development (CORAF/WECARD).

The review was conducted in response to growing need for development of climate change response strategies and policies at different levels, from local to sub-regional scales, in sub-Saharan Africa. Global scientific enquiries have revealed unequivocal evidence that the world's climate is changing and presenting new challenges to almost all spheres of development, as well as threatening the sustainability of current human livelihood systems (e.g. World Bank 2009; IPCC 2007a). Most of the changes in climate have been attributed to anthropogenic factors related to industrialisation and high external input agricultural systems that characterise most of the world's developed nations. Reports of the Intergovernmental Panel on Climate Change (IPCC 2007a; IPCC 2001) demonstrate that while climate change is a global phenomenon, its effects and impacts will be unevenly distributed across the world's geographical regions, ecosystems and human communities. Africa, where most of the world's poor are concentrated, has since been projected to suffer the most negative impacts due to increased temperatures and highly variable rainfall marked by periodic floods and frequent droughts (IPCC 2007b). Both the positive and negative impacts are also likely to be variable within Africa itself.

Empirical research has shown that Africa's farming systems are highly diverse and heterogeneous (Giller et al. 2011), revealing complexities associated with any efforts to target development solutions. This implies critical challenges for decision-makers in formulating relevant climate change response strategies and adaptations policies. It is currently unclear if the research on climate change conducted in Southern Africa in recent years has generated sufficient empirical evidence to inform policymaking processes at the local, national and regional levels. The review therefore had three main objectives:

1. To synthesise the major findings from agricultural research on climate change adaptation conducted in Southern Africa;

2. To identify research and policy gaps on climate change adaptation with a specific focus on Southern Africa's agricultural sector; and

3. To identify key stakeholders and opportunities for climate change adaptation for the agricultural sector in Southern Africa.

1.2 Guiding questions

The review was guided by six major questions as provided in the Terms of Reference of the review call:

i) What is the role of climate change challenges in the context of the multiple challenges and opportunities facing the agriculture sector in the region?

ii) What is the current state of knowledge on adaptation to climate change in the agricultural sector in the region? (section 4)

iii) What is the current state of knowledge on whether and how research findings are integrated in agriculture sector policies in the region? (section 5)

iv) What are the major gaps in research on adaptation to climate change in the agricultural sector? (section 6)

v) What is needed to ensure that research findings are better integrated into the agriculture sector policies? (section 6)

vi) What is the current state of knowledge on the stakeholders involved with research and policy on adaptation to climate change in the agricultural sector in the region, and how stakeholder involvement could be improved? (section 7)

The review also considered four major cross-cutting issues:

- Social differentiation and gender implications
- Implications for water resources
- Cross-scale interactions – national, sub-national and local level
- Focus on smallholders, but also covering commercial, large scale farming where relevant

Providing key recommendations for future research, the review is concluded by highlighting major areas requiring policy considerations.

2 Background and methodology

2.1 Scope of the review

According to the Terms of Reference, the study was expected to deliver based on the following four major tasks:

Task 1. Review climate change adaptation research and policy pertaining to the agricultural sector in a specific sub-region.

- *Undertake a literature search and do a stock-taking, synthesis and analysis of research results related to climate change adaptation in the agricultural sector in your region from the past 15 years.*
- *Map out climate adaptation change policy process and identify the way research has informed policy and major policy players in the region clearly outlining the links between countries and the regional economic body.*

Task 2. Identify gaps in (a) climate change adaptation research and policy in the agricultural sector, and (b) the way research informs policymaking.

- *Based on the review conducted in Task 1, analyse and identify key gaps in research and policy and in the way research feeds into and inform policymaking.*
- *Suggest ways in which these gaps can be closed.*

Task 3. Identify key stakeholders and opportunities for improving climate change adaptation research-policy nexus in the agricultural sector.

- *Identify key stakeholders in adaptation to climate change related to the agricultural sector in your region.*
- *Identify possible opportunities for research, policy formulation and collaboration aimed at enhancing adaptation to climate change in the agricultural sector in your region.*

Task 4. Prepare an overall report comprising three sub-reports corresponding to each of the preceding 3 tasks.

2.2 Defining adaptation to climate change

In the context of this study, adaptation is defined as 'an adjustment in natural or human systems in response to actual or anticipated climatic stimuli or their effects, which moderates harm or exploits opportunities to cope with the consequences' (IPCC 2007a: 869). According to the IPCC (Ibid), adaptation can be anticipatory (or proactive) when it takes place before the impacts are observed. Adaptation can also be triggered by ecological changes in natural systems and by market or welfare changes in human systems. This implies that the adaptation is spontaneous and does not constitute a conscious response to climatic stimuli. This is therefore referred to as autonomous adaptation. The third type is planned adaptation, which refers to the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain or achieve a desired state.

2.3 Adaptation as processes of change leading to reduced vulnerability

The IPCC definition of adaptation in the context of climate change and variability has been commonly linked to the concept of vulnerability, as scientists characterise the susceptibility of natural/human systems and communities to various climatic factors. The concept of vulnerability is commonly used to describe and characterise the exposure by given individuals, communities or systems to named climatic factors, and how sensitive they are to the effects of such factors (Leichenko and O'Brien 2002; Smit and Wandel 2006). Vulnerability is defined as 'the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes' (IPCC 2007a: 869). To this end, vulnerability is thus a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity (Young et al. 2010). The concept can therefore be used to gain a local-level understanding of the ramifications that climate change and variability may have across temporal and spatial scales.

An analysis of vulnerability can focus on the nature and distribution of a specific hazard and the associated degree of loss following the occurrence of a particular event (Young et al. 2010). Alternatively, the analysis can focus on the pre-existing state of a given social system or community that renders it susceptible to harm (e.g.

Downing 2003). Several such analytical studies have revealed the attributes of social systems that can either increase or decrease vulnerability. These include the existence and nature of institutions and governance structures, socio-political factors, equity, economics, food and resource entitlements (Adger 2006; Brooks et al. 2005; Smit and Pilifosova 2003). Studies that unravel the dynamics of these factors (e.g. Dulal et al. 2010) have therefore helped to shift the debate on vulnerability from mere characterisation of the intensities and scales of vulnerability to understanding the underlying processes and how they can be manipulated to promote adaptation. Communities within and across Africa's main sub-regions, including Southern Africa, are characterised by heterogeneity and diversity. The resource bases supporting livelihoods in these communities are also diverse. More empirical evidence is therefore required on the unique processes causing vulnerability for a given community or social system in order to identify opportunities and entry points for promoting adaptation. Identification and better understanding of the current and anticipated negative impacts of climate change will in turn help to inform adaptation options for reducing vulnerability at household and community scales.

2.4 Relation between adaptation, resilience and coping

One of the key outcomes of the IPCC processes is a common understanding by scientists and development practitioners that adaptation to climate change is a local phenomenon. This implies that natural and social (or socio-ecological) systems that are inherently resilient to external shocks are likely to harbour less vulnerable communities, or alternatively, provide a good basis for promoting adaptation processes to reduce vulnerability. Walker et al. (2004) defined resilience as 'the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks'. Thus resilience is commonly characterised in the context of socio-ecological systems. The definition implies occurrence of transformational changes by sub-system components in ways that enable the system to continuously change and adapt so as to remain within critical thresholds (Folke et al. 2010).

In Africa, where more than 70 percent of the population is directly dependent on natural resource pools (e.g. forests and fisheries) and rain-fed agriculture for their livelihoods, ecological resilience is a crucial determinant of social/human systems. Overall, the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages or take advantage of opportunities to cope with the consequences, defines what has been termed 'adaptive capacity' (IPCC 2001). This definition of adaptive capacity recognises that adaptability is part of resilience, as further explained by Folke et al. (2010). The concepts of adaptation, resilience and adaptive capacity are therefore closely linked and account for the continual actions that communities undertake as they seek to cope with the climatic pressures (including hazards) they experience across time and spatial scales. The capacity of households and communities to access and use new information, knowledge and technologies will most likely enable them to generate innovations that allow them to take advantage of any emerging socio-ecological changes and transform their livelihood systems towards adaption to climate change at local levels. Such adaptation processes will enhance resilience at local scales, and will in turn draw on resilience at multiple scales (Folke et al. 2010). On the other hand, adaptation processes that lead to transformative changes at the smaller scales are likely to contribute to resilience at higher (multiple) scales. Lack of adaptive capacity is often due to a poor and diminishing capital base, including continued depletion of natural resources, lack of land and livestock ownership, inadequate financial services (in the form of microcredit, micro insurance and micro savings) and low levels of literacy (Dulal et al. 2010). In related studies, Brooks et al. (2005) found that adaptive capacity has also been significantly associated with governance, civil and political rights and literacy. These findings highlight the critical demands for evidence-based policymaking and informed decision support systems at multiple scales.

2.5 Defining the agriculture sector

Essentially, agriculture is defined as the science, art or practice of cultivating the soil, producing crops and raising livestock, and in varying degrees the preparation and marketing of the resulting products.[1] However, in the context of African livelihood systems, this review adopts an inclusive definition of agriculture that embraces fisheries and forestry. There are particularly strong interactions between crop/livestock production sub-systems and natural sub-systems that include forestry, grazing, fisheries and wildlife. These natural sub-systems form a large part of the resource base that not only supports livelihoods, but also provides a major source of subsidies to the crop-livestock production sub-systems. It is such strong inter-dependencies among the sub-systems which typically define the context of agriculture in sub-Saharan Africa. It is therefore imperative that any current or future focus on climate change adaptation and resilience of livelihood systems in Africa takes into consideration this systems perspective in defining agriculture. Addressing problems at the nexus of agricultural production and natural resources management is thus a major pre-requisite for fostering resilience and achieving sustainable development in Africa. A negative climatic forcing on any of these component sub-systems, which currently define African agriculture, is likely to render diverse households more vulnerable. There is already increasing pressure on forests, water, grazing and other land resources as farming communities use extensive agricultural production approaches to meet their growing food security needs.

Although agricultural systems in different parts of the world have evolved independently, one fundamental factor has commonly defined their success: climate. While commercial exploits of agriculture in developed countries (e.g. America, Europe and Japan) have been underpinned by technical capacity to manipulate key climatic elements such as rainfall (e.g. irrigation), nutrient provision (chemical fertilisers), light and temperature (greenhouses), this has not been the case in many developing countries. For example, only 13 percent of irrigable land in sub-Saharan Africa, out of a total of about 42m hectares, is under irrigation,[2] and fertiliser use[3] still averages below ten kilograms per hectare per year. With over 75 percent of the population dependant on rural livelihood systems, agricultural production is inevitably based on extensive farming approaches. In Southern Africa, most of the farming systems are classified by the UN Food and Agriculture Organization (FAO) as 'maize mixed systems' (Dixon et al. 2001), except in the commercial sector, where systems are specialised but still predominantly rain-fed.

2.6 Methodology used for review

The review was conducted through a desk study looking primarily at refereed journal articles reporting on work conducted in Southern Africa, specifically covering Malawi, South Africa and Zimbabwe. Grey literature and government reports, particularly as they pertained to policy issues, were sourced through individual members of regional and national research and development networks – e.g. the Soil Fertility Consortium for Southern Africa (SOFECSA), African Conservation Tillage Network (ACT) and Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) – and critically reviewed. Grey literature was used more to determine the scope of research covered (or in progress) in each of the countries than as a source of empirical evidence for the major findings. Breakthroughs in finding the limited but relevant literature for the target region were enabled by a systematic search of already archived academic literature on the subject; keyword searches using Google Scholar and related search engines; and expert consultations that took advantage of the community of practice (members of African research networks, colleagues, friends and post-graduate students). Information and knowledge sharing platforms; websites of professional networks; research organisations including the CGIAR Centres; development agencies and major research programs such as Climate Change Adaptation in Africa (CCAA); and funding agencies such as IDRC, the UK Department for International Development (DFID); and that of the United Nations Framework Convention on Climate Change (UNFCCC) provided leads to relevant literature and articles. Overall, 300 articles were reviewed, out of which more than 75 percent were from peer reviewed journals.

2.7 Potential limitations/challenges to the study and measures to mitigate them

Major challenges to this study were related to general scarcity of empirical literature on climate change adaptation conducted in the region of focus. However, the limited studies reviewed revealed current knowledge gaps between policymaking and research processes, and provided insights on how these could be addressed. Reaching key people in both research and policy-related organisations through emails and telephone proved challenging within the study period. However, a significant proportion of them were eventually reached by taking advantage of national and regional meetings and workshops on climate change, including meetings organised by the Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN) and FAO in Zimbabwe and South Africa.

3 Overview of agriculture in the region

3.1 Key facts for the agricultural sector in the region

Agriculture is the economic backbone for most countries in Southern Africa, with South Africa, Botswana and Namibia as notable exceptions.[4] For example, in Malawi agriculture, including forestry and fisheries, accounts for over 30 percent of gross domestic product (GDP) and more than 90 percent of total foreign exchange earnings. With over 80 percent of Malawi's population living in rural areas, it is no surprise that about 90 percent of the country's labour force is employed in agriculture. In comparison, 65 percent of Zimbabwe's population lives in rural areas, and analysis of poverty statistics show that 88 percent of the country's poor live in these rural areas. However, agriculture still accounts for about 20 percent of the country's GDP[5] and employs 66 percent of the national labour force. The economic figures for both Malawi and Zimbabwe contrast sharply with South Africa, where agriculture contributes less than three percent to GDP and accounts for under ten percent of the country's working labour force. Earnings from the mining sector have traditionally driven the South African economy, although there has been a relative increase in the manufacturing and services sectors over the past decade. However, trends in GDP alone may not be a good indicator of the role of agriculture in national economies. For instance, the critical role of agriculture with respect to food security and functioning of informal markets in countries such as South Africa and Botswana may easily be overlooked.

The above mentioned statistics suggest that agriculture will continue to underpin major economic activities for countries such as Malawi and Zimbabwe, providing for food security, national employment and foreign exchange earnings. This analysis is consistent with Southern African Development Community (SADC) figures, which reveal that agriculture is the primary source of subsistence and income for 61 percent (more than 140m people) of the region's population. The major concern, however, lies in the relatively low and variable growth rates of the region's agriculture sector, which has averaged 2.6 percent (Chilonda et al. 2007), against a rising human population and the pending risks associated with climate change and variability. The current growth rate for agriculture is far below the minimum target of six percent set by the New Partnership for Africa's Development (NEPAD) in its Comprehensive Africa Agriculture Development Programme (CAADP) as necessary for attaining overall economic growth, poverty reduction and food security (AU/NEPAD 2003). Poor performance of the agricultural sector in Southern Africa, as elsewhere in sub-Saharan Africa, has mainly been attributed to: under-investment in agriculture by national governments (often below ten percent of national annual budgets); lack of access to production inputs, particularly seed and fertiliser, by farmers; lack of access to output markets; and low levels of development and dissemination of agricultural technologies (e.g. Chilonda et al. 2007). The under-performing agricultural sector could significantly explain some of the prevailing poverty levels. For example, more than half of Malawi's population lives below the poverty datum line, and agriculture continues to be the single major source of livelihood, while in both Zimbabwe and South Africa 70-90 percent of the poor to ultra-poor live in rural areas dominated by smallholder farming (Oettle et al. 1998). Access to land and water are traditionally major constraints for rural communities across these countries. In the Maputo Declaration of 2003, SADC countries committed to increase investment in agriculture to at least ten percent of national annual budgets in response to demands for reducing poverty, but many of the nations have yet to meet this commitment. Southern Africa is still considered a food deficit zone, with food insecurity and malnutrition presenting perennial challenges to national governments (FAO 2010). Average cereal yields in the SADC are between 1.5 and 1.7t/ha, below the sub-Saharan African average of 2t/ha. This is corroborated by SADC regional agricultural policy documents indicating that the region's population is growing faster than its agricultural production (SADC 2012).

Farming systems in Southern Africa can generally be divided into two types: smallholder and commercial. In Malawi, commercial (locally referred to as 'estate') farming accounts for 40 percent of national agriculture, while the remaining 60 percent is smallholder (Chirwa and Matita 2012). However, due to a high population density, over 55 percent of these smallholder households have landholdings of less than a hectare. Cultivation is generally done by hand hoe, and livestock is not a major component of Malawian agriculture except in the northern districts of the country. In Zimbabwe, the smallholder sector accounts for over half of the country's population of one million farming households, and was previously confined to mostly marginal agro-ecologies until the national government's recent land reform programme. The sector has since national independence in 1980 grown to contribute up to two-thirds of the country's total production of major crops such as maize and cotton (Rukuni et al. 2006). The national land reform programme transformed the land ownership structure, geographic distribution of farming systems and the relative contribution to the country's economy by the emergent subsectors. These new subsectors can be classified as: old communal (smallholder); A1 resettled (smallholder); old resettled (smallholder); A2 resettled (commercial) and old commercial. The national statistics on total agricultural output between 2010 and 2012 suggest that smallholder farmers from the old communal areas contributed the most (40-43 percent), followed by the A1 smallholders (20-24 percent) and commercial sector (both A2 and old large scale; about 24 percent) (Government of Zimbabwe 2012a). The contribution from the smallholder sector to crop production is, however, driven mainly by size of cropped area, as average yields were below 0.5t/ha in old communal areas and below 1t/ha in the A1. This indicates critically low levels of productivity, commonly known by research scientists to be driven by poor and declining soil fertility (Mapfumo and Giller 2001; Kumwenda et al. 1995). Statistics also show that about 80 percent of livestock in Zimbabwe (principally cattle) are owned by smallholder farmers (Government of Zimbabwe 2012b). These trends from both Malawi and Zimbabwe, as in many of the less developed countries of SADC (Chilonda et al. 2007), highlight the critical importance of rain-fed smallholder agriculture for achieving both household food security and supporting national economic development.

In contrast, commercial farming dominates agricultural production in South Africa where irrigated agriculture is a major feature of production systems in a country that is predominantly semi-arid. Smallholder agriculture in South Africa is largely perceived as an insignificant part of the economy, and this is apparently fuelling the demise of the sector (Mudhara 2010). However, available empirical evidence suggests that over 4m people in the country's rural areas sustain their livelihoods on subsistence crop and livestock production, making a huge indirect contribution (e.g. in savings on the fiscus) to the economy. Increasing agricultural productivity by this population is likely to yield significant economic and social benefits. To date, the failures in smallholder agriculture, which are largely linked to the legacy of historical apartheid policies and practices (e.g. Manona 2005), have not been fully addressed. The national government has instead endeavoured to address current rural livelihood challenges by putting in place non-agricultural sources such as remittances, off-farm work and government cash transfers (Mudhara 2010). Therefore, a major challenge remains in how to transform smallholder agriculture into a productive sector that can drive rural economic development and reduce vulnerability of nearly 50 percent of the population.

Southern Africa is dominated by rain-fed maize mixed farming systems (Dixon et al. 2001), where the dominant maize-based cropping systems strongly interact with livestock systems (particularly cattle). Rain-fed maize occupies 50-90 percent of cropped farmland in any one year in Zimbabwe and Malawi, and is often monocropped. In fact, only four percent of agricultural land is under irrigation in SADC. Apart from maize, other major staple crops in the region are also cereals: sorghum, millets and to a limited extent upland rice grown in wetland areas and coastal zones of major lakes (e.g. Lake Malawi) and the sea (e.g. in Mozambique). The main complementary crops to the staple cereals include grain legumes such as groundnut, cowpea, Bambara groundnut and common bean, as well as root and tuber crops that include mainly cassava and sweet potato. The legumes have the capacity to capture atmospheric nitrogen and generate protein-rich diets for both humans and livestock, as well as improve the soil nitrogen economy of the farming systems. However, contribution to household nutrition and food security by these legumes, as well as their potential role in livestock production, have been undermined by a number of agronomic and social factors (Mapfumo 2011). For example, much attention at the local and national scales has been given to either cereals or cash crops at the expense of some of the key legumes underpinning household nutrition. Legumes are generally perceived as a 'women's crop' (Mapfumo et al. 2001), suggesting that their production is perceived as a less important household economic activity. This also implies a lesser voice for women in championing production of highly marketable crops. Apart from maize, key cash crops grown across the region include tobacco, cotton, soybean, paprika, wheat, tea, sugarcane and a variety of high value horticultural crops including grapes and flowers. Over the past decade, there has been increased production of tobacco, soybean and cotton by smallholder farmers in Zimbabwe and of tobacco and soybean in Malawi.

Extensive crop-livestock systems characterised by sorghum and millet production are often confined to the drier agro-ecologies, while pure pastoral systems are generally absent in the region. However, there has been a strong trend of rising maize production in these dry eco-zones despite recurrent crop failures due to frequent droughts and poor rainfall distribution even in favourable seasons. On the other hand, there have also been reports of increasing areas cropped to sorghum and millets by smallholder farmers in agro-zones traditionally designated as high potential maize areas in Zimbabwe (e.g. Government of Zimbabwe 2012a). The role of livestock in the farming systems goes beyond the direct value of provision of animal products, as the animals also provide services such as draught power, milk and manure for cropping, as well as act as stores of wealth (Rukuni et al. 2006; Cousins 1997). With the exception of commercial sectors in South Africa, and to some extent Zimbabwe, the agricultural production systems are generally characterised by low external inputs in terms of improved crop cultivars and livestock breeds, fertilisers and agro-chemicals. Common natural resource pools that include aquatic systems, forests and grasslands provide a major source of subsidy to the cropping sub-system through provision of food such as fish; timber and non-timber forest products; ecosystem services; and nutrient resources such as livestock manure and woodland leaf litter (Woittiez 2010; Delve et al. 2001; Mapfumo and Giller 2001).

3.2 The role of climate change challenges

In its fourth assessment report the IPCC projected that Southern Africa will experience longer dry seasons and increased rainfall uncertainty (IPCC 2007a), and this will demand matching adaptation measures. Overall, an analysis of the IPCC data provides evidence of temperature increases of 0.1-1°C between 1970 and 2004 in countries that include South Africa, southeast lowveld areas of Zimbabwe and southern as well as coastal parts of central Mozambique. During the same period, corresponding temperature increases in the rest of Zimbabwe, Malawi and many parts of Zambia, Botswana and Namibia averaged between 1 and 2°C. Such magnitudes of temperature change are anticipated to have a significant influence on the functioning of biological systems including terrestrial and freshwater aquatic ecosystems. An analysis of the IPCC projections (IPCC 2007b; 2001) strongly suggest that Southern Africa will suffer negative impacts in three main areas: i) influence on freshwater resources in lakes and dams; ii) breakdown in resilience of dominant ecosystems; and iii) influence on productivity patterns of food, fibre and forest products.

Southern Africa falls within the regions where a decrease of 10-30 percent in water availability and runoff from rivers is anticipated by the middle of the twenty-first century. This is likely to increase water scarcity in a region already suffering severe water stress for both agriculture and domestic use. Increased frequency of droughts coupled with warmer temperatures and climate-induced floods are likely to force major changes in land use patterns with a high likelihood of over-exploitation of resources drawn from major natural ecosystems (e.g. Campbell 1996). The majority of rural communities are poor and depend on natural resource pools derived from forest and aquatic systems, including non-timber forest products and fisheries. Such disturbances are projected to influence the structure and functioning of ecosystems as ecological interactions and geographical distribution of species are altered. For example, a significant rise in water temperatures is likely to cause a decrease in fisheries resources in large lakes such as Lake Malawi, and over-fishing may also aggravate this. The negative impacts of climate change are therefore likely to be exacerbated by human actions, with even greater consequences for biodiversity and ecosystem services as traditional water and food supply systems are also stretched by a growing human population. The need to enhance food production while maintaining the agricultural resource base and the resilience of the agro-ecosystem will be an increasingly important topic in discussions on the development of the Southern African region in the foreseeable future (Ajayi et al. 2010; Giller et al. 2006).

The IPCC projections suggest that there will be a decrease in growing season length and an expansion of semi-arid and arid zones in the context of agricultural production in Southern Africa. More importantly, localised (specific areas) increases in temperature of 1-2°C are projected to result in decreased crop productivity, significantly increasing the risk of hunger in many communities (IPCC 2007a). Southern Africa is therefore one of the regions where yields from rain-fed agriculture could be reduced by up to 50 percent by 2020, potentially heightening prevailing conditions of food insecurity and malnutrition. This calls for adaptation options that may include changes in crop type and cultivars as well planting times for key crops. However, many of the region's communities are known to be among the world's most vulnerable due to multiple stresses (Casale et al. 2010; IPCC 2007b). For instance, access to improved crop seeds and fertilisers is a major challenge for many smallholder communities in Southern Africa (e.g. SADC 2012). The agricultural sector in the region still suffers from lack of access to appropriate information, knowledge and technologies by different farmers, and this may greatly limit the scope for adaptation.

3.3 State of knowledge on the implications of climate change for other key challenges (and opportunities) for the agricultural sector in the region

One of the major challenges in rain-fed agricultural systems such as those dominating in Southern Africa is the lack of awareness by farmers, agro-service providers and policymakers about past, current and future changes in climate and their implications. The summary report targeted for policymakers already reveals a lack of evidence and good examples from Africa regarding impacts and adaptation options (IPCC 2007a), suggesting a need for deliberately supporting empirical research to address these knowledge gaps. Available findings from empirical research strongly suggest complex interactions and relationships between agriculture and natural resources (including environmental service functions) in driving livelihoods systems in both rural and urban environments. The current and potential impacts of climate change and variability on these systems are therefore less clearly understood given the limited knowledge on major variables explaining these complexities. However, findings from the limited research studies available to date provide some insights on potential areas of development where climate change impacts are likely to have ramifications beyond agriculture and in turn constrain adaptation. Such areas include: i) changes in dynamics of rural-urban interconnections; ii) a shrinking natural resource base and environmental degradation, with poor and declining soil fertility as a critical underlying factor; iii) increased resource use conflicts and breakdown of traditional social safety net systems within/across communities; iv) diminishing marketing and trading opportunities in agricultural produce and derived industrial products; and v) land ownership disputes.

Numerous research studies over the years have helped to explain the intimate relationship between environmental resources (or natural resource pools) and livelihoods in many rural systems (Kepe 2008; Campbell 1996) and the interconnections between rural and urban livelihood systems in Southern Africa (e.g. Andersson 2002). The architecture of urban development in most Southern African countries has tended to discriminate against women, as formal employment historically favoured men who provided much of the labour force during the colonial past. Arguably, this has precipitated a women-dominated (or at least biased) farm labour force, particularly in smallholder areas. However, the working husbands away in urban areas often make strategic farming decisions for these households. Rural communities are therefore often dependant on such services as information and remittances from family members employed in urban areas (Cavendish 2000), while urban communities are often subsidised by rural-based family members and relatives in terms of food provision and sometimes income (Andersson 2001). These social collaborations have tended to provide the much-needed social safety net mechanisms for coping with multiple stress factors including climatic-induced problems. However, the potential value of these collaborations in supporting climate change adaptation has not been critically assessed in the wake of increasing rural-to-urban migration. Conversely, it may be the lack (or collapse) of such social collaborations that triggers conflicts and heightens vulnerability across the rural-urban divide. There is also evidence to suggest that similar social collaborations underpin traditional social safety nets that may have helped to reduce vulnerability of different social groups (e.g. livestock owners versus non-livestock owners) within smallholder communities (Rufino et al. 2011).

Communities in Southern Africa have long been developing strategies and mechanisms for coping with frequent droughts, seasonal crop failure and perennial challenges of food insecurity, which are often associated with poor and declining soil fertility. Most of the communities fall back on common natural resource pools during poor cropping seasons (Woittiez et al. 2013), yet emerging evidence from the IPCC suggest dwindling opportunities for communities to rely on these resource regimes as water resources are projected to decline (IPCC 2007b). While indigenous knowledge regulating the use and sustainable management of these resources has not been given due attention in research and development, there is evidence of significant contribution to household nutrition, food security and income (e.g. Shackleton and

Shackleton 2004). Previous studies in the region have revealed that most smallholder communities derive up to 35 percent of their annual income (Cavendish 2000), and that poorer households get up to 40 percent of their calorie intake during drought years (Woittiez et al. 2013), from common natural resource pools. Kalenga-Saka and Msonthi (1994) found high nutritional values of wild fruits drawn from miombo woodlands in terms of macronutrient elements and energy, while Grivetti and Ogle (2000) found high concentrations of essential micronutrients in a range of fruits from similar environments. High dependence on rangeland products such as fruits and vegetables during times of food scarcity has also been commonly reported elsewhere in Africa (Muller and Almedom 2008). However, the studies have also shown that access to these resources is highly differentiated according to gender, age of household heads, wealth status and composition of households (e.g. Woittiez 2010; Cavendish 2000). Poorer households, who often comprise a high proportion of women-headed families, rely more on the common pool resources (Woittiez et al. 2013), and therefore the negative impact of climate change on the natural resource base has strong implications on their livelihoods.

Such studies reveal diverse livelihood benefits derived from forests and rangelands (Kepe 2008). Although social, economic and political factors often comprise the major factors driving conflicts related to issues of access and distribution of natural resources, it is also apparent that conflicts may arise due to multi-dimensional and competing resource uses and ownership claims. Such conflicts occur not only within and among communities (e.g. for land and water), but also between people and both domestic animals and wildlife (Giller et al. 2008). There is clear evidence that communities attach value to common natural resource pools (forests, fisheries, rangelands, etc.) beyond current considerations (Kepe 2008; Shackleton et al. 2001), but it is still unknown how these values are likely to change as relationships and interactions among cropping, livestock and natural sub-systems are altered in time and space by increasing pressures of climate change and variability. Climate change impacts are exerting additional pressures on an already diminishing natural resource base for most communities, calling for extraordinary adaptation solutions to sustain agricultural productivity and develop new income opportunities for the young and growing populations. This may require new forms of production technologies and institutions as the size and quality of land and environmental resources decline.

4 Climate adaptation research in the agricultural sector

4.1 Vulnerability and adaptation of crop farming systems in the region

4.1.1 Scientific evidence for implications of climate change

The IPCC projections of increasing air temperatures in Southern Africa are confirmed by a number of empirical research studies from Malawi, South Africa and Zimbabwe. Yearly average air temperatures in South Africa were found to increase at a rate of 0.13°C per decade between 1960 and 2003 (Abraha and Savage 2006; Kruger and Shongwe 2004). However, some of the downscaled models projected temperature increases of 2-3°C, particularly in the interior of the country (Johnston et al. 2012). In Zimbabwe, Unganai (1996) found an increasing trend in mean maximum temperatures of 0.1°C per ten year period between 1933 and 1993, with an overall increase of up to 0.8°C. However, localised temperatures in areas such as the capital Harare increased by up to 1.2°C over the same period, suggesting uneven distribution of the warming even at local scales. The downscaled models used by Unganai (1996) also predicted that a doubling of atmospheric CO_2 mean air temperature would increase by 2-4°C. Almost a decade later, Mugabe et al. (2012) used four downscaled Global Circulation Models (GCMs) derived from IPCC and predicted a 1.5-2°C increase in annual maximum temperatures for the period up to 2050 in most of the country, based on two of the models (CSIRO and MIROC). One of the other two models suggested a 2.5-3°C increase for most of the country and a possibility of 3.5°C in the country's western areas within the same period. Climatic data from Malawi showed that mean and maximum air temperatures increased by 2.3 and 2 percent respectively between 1970 and 2002, and projections up to 2050 also suggest increased warming. The same GCM models used for South Africa and Zimbabwe predicted increases in air temperature of 1-1.5°C for the northernmost parts of the country, and 1.5-2°C for the rest of the country (Saka et al. 2012). While the predicted temperatures vary with geographic areas within countries and also with the specific model used to make the projection, the bottom line is that all models predict a significant warming for the region. This is already consistent with observed patterns from historical field data analysed in each of the countries.

The observed and projected increases in air temperatures have generally been linked to a significant decrease in rainfall in Southern Africa. Unganai (1996) analysed long-term rainfall figures between 1900 and 1993 and concluded that there was a 10 percent decline in rainfall over the period. However, the major challenge for cropping systems is likely to come from deteriorating quality of rainfall seasons. A critical analysis of rainfall data from over 40 different stations in Zimbabwe revealed no changes in total annual rainfall, but rather highly significant increases in within season variability (Mazvimavi 2010). This is confirmed by an emerging body of empirical research suggesting that critical challenges for cropping systems will arise more from increased intra-seasonal variability in rainfall rather than the mere total amount received per season (e.g. Rurinda et al. 2012). Episodes of floods characterised sometimes by a whole seasonal total received within a single month, followed by conditions of drought within the same season, have been common in Southern Africa.

Several studies have revealed that a combination of increased rainfall variability and increasing ambient air temperatures will in turn cause a significant decline in yields of major staple crops, particularly maize (Dixon et al. 2003; Kiker 2002; Phillips et al. 1998; Makadho 1996). Most of the regional studies have therefore used simulation modelling to evaluate the potential effects of projected rainfall variability on production of major crops, particularly the staple maize that has a strong bearing on food security. In South Africa, each one percent decline in rainfall is predicted to cause a 1.1 percent decline in maize and a 0.5 percent decline in winter wheat production (Bilgnaut et al. 2009). Gbetibouo and Hassan (2005) also predicted reduced yields for a variety of crops including maize, wheat, sorghum, sugarcane, groundnut, sunflower and soybean due to increased rainfall variability and warmer ambient temperatures. Taking advantage of a wide network of field trials by international and national research networks across Africa, Lobell et al. (2011) used a data set of more than 20,000 historical maize trials in combination with daily weather data and showed that for each degree day spent above 30°C final maize yield was reduced by one percent under optimal rain-fed conditions, and by 1.7 percent under drought conditions. Furthermore, maize yields are projected to decline by up to 20 percent in the next 50 years in Malawi (Ibrahim and Alex 2008; Lobell et al. 2008), and by 10-57 percent by 2080 in Zimbabwe (Fischer et al. 2005; Lobell et al. 2008) mainly due to increased rainfall variability. A revelation from these various studies is that the highest losses in production will be in areas traditionally considered as of high agricultural potential, with serious implications for an already food insecure region. Major losses in production of staple cereals will be due to a rainfall-induced shrink in areas suitable for production: that is, the loss of current high potential agro-ecologies.

Researchers have also used different simulation models to evaluate the implication of the IPCC-based projections (mainly SCIRO and MIROC models). For example, in South Africa, the Decision Support System for Agro-technology Transfer (DSSAT) crop model projected significant maize yield reductions in the current medium to high potential areas by 2050 in relation to the 2000 yield levels (Johnston et al. 2012). Yield increases were, however, projected for some of the country's provinces that include Northwest and areas that are currently considered too cold for maize production in the Free State and Eastern Cape provinces. On the other hand, significant wheat yield increases were projected for Free State and Mpumalanga provinces (Ibid). Using the IMPACT global model for food and agriculture, the area suitable for maize production in South Africa was projected to decline by 25 percent between 2010 and 2050, raising concern that the country could become a net importer of maize if no countermeasures are taken. The model, however, showed that sugarcane was the most resilient crop that showed potential for increased yield across large areas in the country (Ibid). Similar work in Malawi using DSSAT showed that most of the central and northern regions of the country will witness 5-25 percent increase in maize yields in the period to 2050, while the southern region will have large areas facing threats of a 5-25 percent yield decline (Saka et al. 2012). However, the areas with a potential for more than 25 percent maize yield increase were mainly found in the western areas of the country's southern region. Over the same period, the IMPACT model projected no significant changes in areas grown to maize, but a significant decrease in area under cassava, causing a decline in total production despite prospects of a 50 percent increase in yield for the crop. There is therefore a high probability that the country will be a net importer of cassava within the 40-year period under consideration. The model, however, projected a doubling of cotton production due to increased yields, although land shortage is expected to limit any possible expansion in cotton production area (Saka et al. 2012). In Zimbabwe, similar DSSAT projections based on SCIRO and MIROC models produced inconsistent results on both maize and sorghum yields. With SCIRO, significant areas in the country were projected to suffer a 5-25 percent maize yield loss for the period up to 2050, while many areas were expected to witness a 5-25 percent increase in yields under the MIROC scenario (Mugabe et al. 2012). Using the CERES-Maize mode in earlier studies, Makadho (1996) concluded that maize production would become an unacceptably riskier agricultural activity for most smallholder farmers in Zimbabwe mainly due high ambient temperatures triggering moisture stress during grain filling. These findings and projections suggest new challenges in managing cropping systems in the future, and have a bearing on potential adaptation options to reduce vulnerability of the cropping sub-sector in agriculture given the multiple challenges that farmers face.

While the foregoing discussion shows the value of modelling in informing future options for climate change adaptation in agriculture, it also reveals the glaring knowledge gaps arising from lack of field data on how farmers' current decision-making process may or may not influence the projected outcomes. For example, analysis of inter-seasonal rainfall variability (Tadross et al. 2005) and intra-seasonal rainfall patterns (Tadross et al. 2009) in Southern Africa highlight major challenges for supporting farmers' strategic (long-term), tactical (between seasons) and operational (within season) decisions to minimise/avoid risk or take advantage of any emerging opportunities at local scales. Tadross et al. (2009) projected an increase in mean length of dry spells and a reduction in rainy day frequency in Southern Africa, making farmer choices of planting dates and selection of crop types/varieties critical. The study suggested that early planting may not necessarily be a solution in certain seasons due to prolonged dry spells, yet late planting may also render crops susceptible to diseases and pests outbreaks induced by late rains. Studies by Tadross et al. (2005) provide insights on how improved understanding of climatic factors controlling critical seasonal rainfall events such as onset and cessation could improve targeting of adaptation options. Decision-making processes for many in Southern Africa, particularly the smallholders in Malawi and Zimbabwe, are undermined by numerous constrains that include lack of timely access to affordable agricultural inputs, volatile output markets, lack of access to climate information and lack of access to land and improved production technologies. These factors add to the complexity problems defining the scope for vulnerability of farming households drawing livelihoods primarily from rain-fed cropping systems.

4.1.2 Causes of vulnerability

As noted above, the definition, and therefore conceptual understanding, of the term 'vulnerability' is often different within and among different groups of practitioners in research and development (Casale et al. 2010; Miller et al. 2010; Vincent 2004). However, there is a general consensus that farmers in Southern Africa and other parts of sub-Saharan Africa are exposed to different stress factors associated with global environmental (e.g. climate change), economic and socio-political change processes, and that the response capacities of these communities are limited. Agriculture accounts for livelihoods of the majority of Southern Africa's population, either directly or indirectly through employment in agro-based industries. One can argue that the major causes of vulnerability to climate change and variability in the region are inherent in the very traditional problems known to constrain agricultural systems, with the emerging impacts of climatic change presenting a new context for interpretation of these challenges. Farmers in the region, as elsewhere in Africa, are often faced with multiple stress factors (Casale et al. 2010; O'Brien et al. 2009) that in effect can define the complex interactions underpinning their adaptive capacity (or lack thereof).

There are more commonalities than differences in the major causes of vulnerability to climate change of households and communities in many Southern African countries. These can be classified as outlined below, and the multiplicity of stress factors defining the context of adaptive capacity by diverse communities against the effects of climate change and variability are also explained:

i) *High dependence on climate-sensitive crop production systems:* The predominantly maize-based (including other cereals and leguminous crops) and rain-fed cropping systems of Southern Africa are dependent on season quality on a year-to-year basis, and susceptible to weather extremes of droughts, floods, storms and extreme temperatures (Unganai and Murwira 2010; Dixon et al. 2003; Makadho 1996). For example, any negative effects of climatic factors will affect over two-thirds of Zimbabwe's rural population who live directly on proceeds from agriculture. In Malawi, about 85 percent of the population (51 percent of whom are women) are based in rural areas where they depend on rain-fed crop production (Government of Malawi 2002). South Africa also presents a good example of contrasting scenarios showing how the heavy dependence on climate-sensitive agricultural systems may be a major source of vulnerability. The Western Cape and Gauteng provinces, which have high levels of infrastructure development, high literacy rates, and low shares of agriculture in total GDP, are relatively low on the vulnerability index. In contrast, the highly vulnerable regions of Limpopo, KwaZulu Natal and the Eastern Cape are characterised by densely populated rural areas, large numbers of small-scale farmers and high dependency on rain-fed agriculture (Hachigonta et al., 2013; Midgley et al. 2002). More than 70 percent of the South African's poor population resides in rural and informal settlements where their livelihoods are dependent primarily on crop production. Overall, the region's over-dependence on maize may in itself be a source of vulnerability for millions of people, although this may also present opportunities to draw on technology advancement in crop improvement and management of crop interactions that involve maize. During the past decade researchers have begun to explore mechanisms for getting smallholder farmers out of the 'maize poverty trap' (Nyikahadzoi et al. 2012; Mapfumo 2011; 2009). A major revelation from this research is that: unless there is sufficient maize on the market, communities will continue to grow the staple crop despite the high rates of production failure. Intensification of the maize-based systems is therefore considered a pathway to diversification (out of the maize trap) into alternative high value crops (Mapfumo 2009), but this calls for supporting policies on intensification and diversification.

ii) *Poor and declining soil productivity:* Granite-derived soils dominant in many parts of Southern Africa present some of the world's most challenging soils in terms of their inherently low nutrient supply capacity, low soil organic carbon contents and poor water retention capacity (Mafongoya et al. 2006; Mapfumo and Giller 2001). Poor soil fertility is one of Africa's major developmental challenges

(Bationo 2004; Sanchez et al. 1997). The poor and declining soil fertility under maize monocropping inevitably results in a diminishing land quality with several concomitant externalities including agricultural extensification (Mapfumo 2009) and conflicts related to access to land resources (Rukuni et al. 2006; Lahiff, 2007). Pressure on existing land resources due to low use of external nutrient inputs resulted in alarming rates of nutrient mining and declining crop yields (Mtambanengwe and Mapfumo 2005; Stoorvogel and Smaling 1998), and accelerating land degradation as farmers encroach into marginal and fragile lands for cultivations. A combination of unproductive soils, poor access to fertilisers and alternative nutrient resources, and increased climate variability is a recipe for absolute disaster for crop production in Southern Africa.

iii) *Land degradation and a diminishing natural resource base:* Low productivity levels on crop lands often result in annual food deficits at household and community scales (Nyikahadzoi et al. 2012; FAO 2010), leaving many households to rely on food aid and/or food gathering from common resource pools such as forests, woodlands, rangelands and fisheries (e.g. Kepe 2008). However, increasing population pressure and a general decline in productivity and size of these common lands have increasingly contributed to land degradation and desertification. For instance, between 1990 and 2010 Malawi lost about 17 percent of its forest cover to agricultural expansion, growth of human settlements and harvesting of domestic fuel wood against low levels of reforestation (FAO 2011). Poor performance of cropping systems due to climate change will, therefore, not only increase threats of land degradation (Davies et al. 2010; Kazombo-Phiri 2005; Carr 2003), but also undermine provision of ecosystems services that have traditionally supported livelihoods of many poor households.

In South Africa, the most sensitive regions to climate change are Limpopo, KwaZulu Natal and the Eastern Cape, because of severe land degradation and reduced natural production capacity. According to Meadows and Hoffman (2002), the Eastern Cape, KwaZulu Natal and Limpopo possess a combination of physical and socio-economic factors (both contemporary and historical) that have led to significant, and in some cases irreversible, levels of deterioration in the rural environment. The least sensitive regions are the Western Cape, Gauteng and Free State. A common feature of these regions is that they have a low percentage of subsistence farmers and have the least populated rural areas. Research findings from different countries indicate that smallholder communities in Southern Africa strongly rely on natural resource pools to sustain their livelihoods during drought years or poor cropping seasons (Woittiez 2010; Frost et al. 2007; Mapedza et al. 2003; Campbell et al. 1993). Any threats on this resource base due to negative impacts of climate change will therefore render many households even more vulnerable.

iv) *Lack of timely access to crop production inputs, and to output markets:* Numerous studies have shown how poor access to crop inputs such as seeds, fertilisers, herbicides and equipment has remained a perennial problem for the majority of predominantly smallholder farmers in Southern Africa (SADC 2012; Government of Malawi 2008; Mtambanengwe and Mapfumo 2009; Chilonda et al. 2007; Kazombo-Phiri 2005; Carr 2003). Smallholder cropping systems, upon which most of the vulnerable communities depend, have mainly been centred on a subsistence mode of production in which endogenous input components are maximised while external inputs are minimised. Many of the farmers, by design, therefore live beyond the reach of markets, yet agricultural development policies are hinged on principles of (assumed) market participation. Transformation of these subsistence farms into commercially oriented production systems driven by market objectives (e.g. Delgado 1999), therefore, effectively demands for structural and process changes in knowledge systems, technology development and delivery, institutions and policies.

Climate change and variability exerts further demands for such transformations, bringing to the fore questions on potential links between vulnerability and functioning (or failures) of agricultural markets at different scales. The rise of smallholder agriculture in post-independent Zimbabwe (before the recent socio-economic and political crisis) (Rukuni et al. 2006), and experiences from Malawi's recent subsidy programme (Ricker-Gilbert et al. 2011; Dorward and Chirwa, 2011) present some key lessons on the value of input-output market access. However, such efforts to increase productivity and commercialise smallholder agriculture have also increased the necessity for external input use, with disproportionate livelihood impacts against poorer households and communities in remote areas (Mapfumo et al. 2013; Nyikahadzoi et al. 2012). Due to increased rainfall variability, use of purchased crop inputs has not only become riskier, but also critically dependent on timing of operational decisions by farmers. There is evidence that farmers with better access to seasonal climate forecasts are better able to make appropriate farming decisions at the farm level and get better harvests (Patt et al. 2005). However, lack of access to inputs often remains an overriding constraint (Mapfumo et al. 2013; Patt et al. 2005).Development of models for supporting access and efficient use of agricultural inputs by diverse categories of farmers and supporting their timely responses to climate forecasts is therefore a major challenge for development researchers and practitioners in their planning of adaptation interventions. Empirical evidence is critically lacking on how timely access to agricultural inputs and output markets can reduce or heighten vulnerability of farming communities under current and future changes in climate change.

v) *Lack of access to information and knowledge:* One major cause of vulnerability in the agricultural sector is the lack of access agricultural information and knowledge by farmers and local level service providers (e.g. local extension agents), on climate forecasts, early warning systems, improved agricultural technologies and practices and available options for adaptation. The limited information accessed in most African rural communities has also tended to discriminate against women and socially disadvantaged sections of local societies. Farmers depend more on their indigenous (local) knowledge systems and own social networks than conventional scientific knowledge systems for decision-making (Mapfumo et al. 2010a; Nyong et al. 2007). Farmer decisions on what crops/cultivars to grow, when to plant, as well as when to sell how much of their crops, are therefore not informed by robust (science-based) evidence. However, the value of indigenous knowledge in development (e.g. Tanyanyiwa and Chikwanha 2011; Pawluk et al. 1992; Warren 1991) is worth recognition. Communities have historically managed to adapt to climate and other environmental stresses, albeit with severe trade-offs. However, there is a general lack of supporting evidence on how local knowledge systems may or may not be sufficiently understood, or are simply not adequate to inform farmer decisions on sustainable adaptation options to match the magnitude of current and future challenges due to climate change and variability. The nature and magnitude of emerging impacts of climate change are likely to present adaptation demands that are beyond the scope of current local knowledge systems, potentially rendering most of the communities vulnerable. Studies in Zimbabwe and South Africa have shown that farmers have a varied understanding of the major causes of climate change and variability, the current and potential impacts and the need for adaptation (Mtambanengwe et al. 2012; Gbetibouo 2008), suggesting a general lack of equal access to quality climate and agricultural information by farmers (Dutta 2009). The usefulness of seasonal climate forecasts has often been undermined by lack of credibility, coarseness of scale and institutional barriers, among other factors (Patt and Gwata 2002).

There is increasing evidence that participatory action research, learning-based research and development approaches enhance access to information/knowledge by farmers in general, and the hitherto marginalised social groups in particular, allowing them to experiment with new technologies and potential adaptation options (Mapfumo et al. 2013; 2008). Evaluation of work of SOFECSA in Zimbabwe showed that about 73 percent of the farmers preferred interactive farmer learning platforms to access information on integrated soil fertility management (ISFM) and other agricultural knowledge (Gwandu et al. 2013). In contrast to findings from related studies in the health sector in the region,[6] farmers' least preferred sources of information included non-governmental organisations (NGOs), newspapers and magazines (Ibid). There is also evidence suggesting that participatory workshops enhanced use of climate forecast information by farmers (Patt et al. 2005). Lack of access to information renders irrelevant the role of climate early warning systems, leading to poor preparedness against climatic hazards such as droughts and floods (Unganai and Murwira 2010).

vi) *Weakening of local institutions and traditional social safety net systems*: Farming communities have always coped with multiple stresses as they struggle to sustain their livelihoods, probably accounting for some of the diversity and complexity of agriculture and natural resource management systems that have kept them going for generations.

However, it has become evident that collapsing components of traditional social safety net systems will likely increase vulnerability of households and communities. These include the following: i) breakdown of rural-urban links (e.g. Andersson 2002; Smith 1999); ii) weakening extended family systems (Casale et al. 2010); and iii) weakening of local institutions that have traditionally supported social collaborations and minimised conflicts to achieve food security (Mapfumo et al. 2013; Chilowa 1998), enhanced management of crop-livestock interactions (Rufino et al. 2011) and regulated use of natural resources such as forestry and fisheries (Campbell 1996). High profile development projects that hold high promises (e.g. through environmental conservation and economic benefits), as well as interventions anchored on compliance to donor-driven but frequently changing buzzwords, have sometimes tended to heighten vulnerability rather than reduce it (e.g. Andersson et al. 2012; Büscher and Mutimukuru 2007). Many food aid and relief programmes championed by governments and NGOs have also apparently contributed to erosion of the core values of local social safety nets, often rewarding laziness among communities and weakening their adaptive capacity (Mapfumo et al. 2013). Casale et al. (2010) demonstrated the strong links between external sources of vulnerability such as lack of employment or income and internal sources such as a lack of adequate education that in turn undermine the ability to secure employment. These examples suggest vulnerability of local institutions to external pressures, which in turn further exposes communities and households to emerging threats of climate change. This also points to the intricate poverty traps that commonly characterise livelihoods of poor communities in developing countries, which if not unravelled and clearly understood in the context of climate change, may instead result in development of adaptation options that undermine some of the current and future sources of resilience. Dercon (2007) defined a poverty trap as an equilibrium outcome or situation from which one cannot emerge without outside assistance/intervention, and this is often caused by market failures which force farmers into low risk-low return livelihood options (Dercon 2011; 2009).

vii) *Poor and diminishing capital resource base:* Most households and communities lack the capacity to use or create new off-farm livelihood opportunities due to their current levels of poverty, and it is unlikely that they will be able to respond to additional livelihood pressures, or even take advantage of any opportunities, associated with climate change and variability. For instance, Malawi is one of the world's poorest countries, ranking 160th out of 182 countries on the Human Development Index. According to the United Nations Development Programme (UNDP) Human Development Report for 2009, about 74 percent of the population still lives below the income poverty line of US$1.25 a day and 90 percent below the US$2 a day threshold. The proportion of poor and ultra-poor is highest in rural areas of the southern and northern parts of the country (World Bank 2008; Ellis et al. 2003). Lack of education coupled to physical exclusion from major national economic initiatives due to poor infrastructure present major barriers to climate change adaptation. Communities often lack access to infrastructure such as land, roads, bridges, health and education facilities and water supply structures, and are often not primary beneficiaries of financial services such as microcredit, micro insurance and micro savings (Government of Zimbabwe 2013; Unganai and Murwira 2010; World Bank 2008). The communities are, therefore, practically trapped, with limited alternative livelihood options outside agriculture for most of the rural communities.

viii) *High prevalence of HIV/AIDs, malaria and other diseases:* Labour productivity in the agricultural sector in Southern Africa has continued to be severely compromised by the scourge of HIV/AIDS. The region has witnessed prevalence rates as high as 25-40 percent in many of the countries, creating a great strain on the health delivery system and indirectly impacting on other livelihood systems (Casale et al. 2010).For example, it is projected that farmers in areas such as the Limpopo, KwaZulu Natal and the Eastern Cape provinces are unlikely to cope effectively with the potential impact of climate change and variability due to high unemployment and HIV prevalence, and low infrastructure development (O'Brien et al. 2009; ASSAf 2007; Government of South Africa 2004). There are numerous reports of labour constraints as family members spend significant time looking after the sick. Weakening institutional arrangements and social networks have also been found to aggravate the risks associated with loss of labour in the agricultural sector (Casale et al. 2010; SADC 2003).

4.1.3 Options for strengthening adaptive capacity and supporting crop farming-based livelihoods

Building adaptive capacity of farming communities in Southern Africa will require a consideration of the diverse farmers' production objectives and resource endowments, and understanding of differential impacts of pending climatic threats on different social groups within and across communities (e.g. women, youth, the elderly, migrant households and the disabled) in order to appropriately target adaptation options across temporal and spatial scales. Sustainable adaptation options are likely be those rooted in local knowledge systems and institutions. Strategies for building adaptive capacity in Southern Africa are therefore likely to differ significantly between the large scale commercial and smallholder sectors. The commercial sector is often characterised by a big capital base and high organisational capacity drawn from their diverse private, corporate and public ownership structures. Typically, the farmers have larger cash flows and greater diversification, can afford longer planning horizons that take advantage of easy access to credit, and have the capacity make capital investments and respond to market fluctuations (Thomas et al. 2011). Building their adaptive capacity is therefore likely to involve support mechanisms and policies that enhance technology development and adoption, crop diversification, innovative insurance strategies, and improved financial and risk management (Challinor et al. 2007). In contrast, the smallholder farmers present a more complex scenario because of their heterogeneity (Giller et al. 2011) and their intricate but resource-constrained livelihood systems. Thus climate adaptation interventions for smallholder communities will necessarily require fostering capacity for multi-dimensional responses (socio-political, economic and ecological) and change processes that can transform both agricultural and livelihood systems.

Research studies in Malawi, South Africa, Zambia and Zimbabwe under the IDRC-DFID funded CCAA programme demonstrated the potential role of a combination of participatory action research (PAR), field-based co-learning, participatory technology development approaches and innovation systems in building the adaptive capacity of different smallholder communities (Mapfumo et al. 2013; 2008; Majule et al. 2011; Twomlow et al. 2008). Interventions that significantly influenced social change processes with positive feedback on local institutions were those that enabled access to improved crop types/cultivars and ISFM technologies to address food security concerns and enhanced market participation by farmers (Mapfumo et al. 2013). The interventions demonstrated that PAR and farmer co-learning platforms could be coupled to support smallholder farmers to self-mobilise and self-organise for collective action processes that included natural resources management, joint acquisition of agricultural inputs and marketing of produce. These processes promoted farmer-to-farmer sharing of information and knowledge on ISFM as an adaptation option (Gwandu et al. 2013), and contributed to enhancement of household food self-sufficiency (Nyikahadzoi et al. 2012). Lessons can be drawn from these limited CCAA projects to provide insights on appropriate approaches for building adaptive capacity of the poor and socially disadvantaged (hence more vulnerable) communities. The following are options for crop-based climate change adaptation by smallholder farmers in Malawi, South Africa and Zimbabwe, as suggested from the various studies:

- Enhancing interactions between planting time and soil fertility management technologies for optimising crop yields under variable rainfall and changing temperature regimes (Mapfumo et al. 2013; Crespo et al. 2011; Zinyengere et al. 2011).

- Promoting timely access to sufficient quantities of quality crop production inputs by farmers in order to enhance timeliness of farming operations in response to the dictates of prevailing climatic factors. This includes access to fertilisers, seed, herbicides and farming equipment.

- Improving access to and use of soil, water and natural resources management technologies including ISFM technologies (Mtambanengwe and Mapfumo 2008; Mafongoya et al. 2006), conservation agriculture (CA) options (Thierfelder and Wall 2010; Unganai and Murwira 2010), land reclamation/restoration options (e.g. agroforestry and indigenous legume fallows), natural resources management approaches (Nezomba et al. 2010; Akinnifesi et al. 2008; Mapfumo et al. 2005) and integrated water management strategies and techniques (Maponya and Mpandeli 2012; Nyamangara and Nyagumbo 2010; Theu et al. 1996). However, the relative contributions of these options to climate change adaptation processes still require quantification.

- Crop diversification into stress tolerant crop types and cultivars, including mixes of: perennial versus short cycle cultivars; cash crops versus subsistence crops; root and tuber crops versus staple cereals; and high yielding crop types and cultivars to take advantage of known windows of favourable climatic conditions (e.g. rainfall and temperature) (Bryan et al. 2009; Dinar et al. 2008; Benhin 2006). Crop improvement research to develop stress tolerant crop cultivars is therefore a necessity (e.g. Bänziger et al. 2006).

- Switching to more water efficient crops such as sorghum or millet or changing production entirely from crops to livestock (Kiker 2002; Makadho 1996).

- Integrating stress tolerant nitrogen fixing legumes into the cropping systems to enhance soil productivity and improve household nutrition and income (Mapfumo 2011; Adjei-Nsiah et al. 2008; Waddington and Karigwindi 2001; Mpepereki et al. 2000; Kasasa et al. 1999).

- Development of irrigation infrastructure including construction of small to medium dams in smallholder farming areas to complement rainwater (Bryan et al. 2009; Matarira et al. 2004; Kiker 2002).

- Developing mechanisms for enhancing efficiency of resource targeting at field, farm and community scales (Tittonell et al. 2012; Giller et al. 2006) including options for mineral fertiliser management in response to within season rainfall patterns, and strategic management of mineral and organic fertiliser combinations (Chikowo et al. 2010; Kanonge et al. 2009; Ncube et al. 2007; Piha 1993).

Building research and extension capacity at different levels for technology development, adaptive testing and participatory monitoring and evaluation of change processes associated with the above options will apparently provide a major avenue for their implementation. Government facilitated provision of financial aid, credit, insurance and market incentives to both commercial and subsistence growers may enable famers to respond adequately to more challenging cropping environments (Bryan et al. 2009; Kiker 2002). Other suggested supportive measures include: promotion of diversified employment opportunities; new institutional arrangements; and communal risk sharing measures to conserve resources (Challinor et al. 2007). Running comprehensive HIV/AIDS programmes can also enhance agricultural labour productivity and redirect resources towards other adaptation options.

4.1.4 Documented adaptation by farmers in the region

Farmers have responded to climate variability through a variety of crop management strategies, although most of these efforts may qualify more as coping than as adaptation strategies. This can be attributed to the fact that farmers have long been living with climatic problems such as droughts, flooding and within season rainfall variability, but it is only in recent years that awareness on the magnitude of the problem has been raised. This may therefore explain the limited practical evidence available on adaptation measures that have been pursued by farmers to date. Most of the available examples are notably related to food security, suggesting reactive rather than anticipatory or planned adaptation actions by most farming communities. Tropical Southern Africa is dominated by miombo ecosystems (Campbell 1996) and a number of rural institution have evolved over time to regulate harvesting and distribution of livelihood benefits among rural communities (Magombo et al. 2012; Shackleton and Shackleton 2004; Clarke et al. 1996). Smallholder communities have continued to depend on their indigenous knowledge to extract of wild fruits and other non-timber forest and rangeland products, particularly during years of poor harvests and drought (Woittiez 2010; Frost et al. 2007; KalengaSaka and Msonthi 1994). An important source of adaptation from these activities is the evolution of functional community-based natural resources management regimes (Roe et al. 2009; Mutimukuru et al. 2006). This has not only given rise to better opportunities for community mobilisation and organisation towards natural resources conservation, but has also increased consciousness among external stakeholders in development about the value of local institutions and the role they can play in anchoring solutions to emerging environmental threats.

Commonly documented adaptation options employed by farmers directly in management of crop systems include (re)introduction of mixed cropping, and planting of short season maize varieties and other crops to allow early harvesting and shortening of hunger periods (Stringer et al. 2009; Orr and Mwale 2001). Farmers have also tended to move towards mixed crop-livestock farming (Magombo et al. 2012; Benhin 2006). Detailed case studies from southern Mozambique (Milgroom and Giller 2013) and northeast Zimbabwe (Rufino et al. 2011) showed how local institutions have evolved out of environmental marginality to yield social

Box 1: Selected examples of climate change adaptation studies and interventions conducted in Malawi, South Africa and Zimbabwe

- Combined use of participatory action research (PAR) and learning centre approaches to revitalise local institutions supporting traditional social safety nets and uptake of integrated soil fertility management (ISFM) technologies and improved agronomic practices (*e.g. managing planting date x nutrient management interactions for different crop types and cultivars*) by smallholder farming communities in Makoni and Wedza districts of eastern Zimbabwe (Mapfumo et al. 2013). The studies enabled quantification of the contributions of forest and rangeland resources to farmer livelihood during climatic stress (Woittiez et al. 2013).

- Assessment of local climate change adaptation strategies used by farmers in Malawi, such as crop diversification, temporary migration, selling of assets, eating of a wild tuber plant called *Nyika*, small-scale irrigation and application of organic manures for soil fertility enhancement. These options were promoted at scale by the government, donor community and civil society in order to build adaptive capacity of communities and resilience of the farming systems against the impacts of climate change and variability (Magombo et al. 2012; Matiya et al. 2011). Prioritised interventions included diversification into early maturing and drought tolerant maize and sorghum varieties (Magombo et al. 2012).

- Initiatives by Practical Action and Lutheran Development Services (LDS) focused on mainstreaming of climate change adaptation and disaster risk reduction at district, provincial and national levels through use of community based approaches (CBA) so as to empower local communities in decision-making processes in Zimbabwe. This enabled adoption of a livelihoods centred approach to disaster risk reduction, which marked a policy departure away from post disaster emergency response (Brown et al. 2012).

- Coping with drought and climate change project in Chiredzi district in southeast Zimbabwe (Government of Zimbabwe/UNDP/GEF 2009; Unganai 2009). Focusing on developing adaptation strategies for smallholder farmers, the project employed principles of participatory decision-making, planning and implementation. One of the key objectives was to promote access and use of medium- to long-term climate forecasts to inform decision-making processes in livestock, cropping and water management as well as off-farm activities.

- Promotion of conservation agriculture (CA) and related farming practices by various development partners as an adaptation strategy in drought prone areas. Apart from provision of inputs, smallholder farmers have received new knowledge that enabled them to try new options for adaptation (Gukurume 2013; Gukurume et al. 2010; Mutekwa 2009).

- In South Africa, large-scale commercial farmers have shown promise to adapt through technology development and adoption, crop shifting and diversification, insurance and improved financial management (Challinor et al. 2007).

- Activities of the Zvishavane Water Projects (Zimbabwe) demonstrated that building on farmers' indigenous knowledge, skills and experience through soil and water conservation technologies such as water harvesting activities enabled farmers to adapt to harsh climatic conditions prevailing in this area (Mutekwa 2009). Provision of climate forecast information in a language that is understandable to farmers on warnings of poor season, commencement of season and adequacy of rains also proved a useful entry point for informing decision-making processes (Unganai 2000; Phillips et al. 2001; Patt et al. 2005).

collaborations that offer options for adaptation to climate variability by smallholder communities in semi-arid zones. Collaborations that provided for land and draught power (cattle) exchange allowed Mozambican farmers to stagger their plantings and maximise staple cereal production during favourable seasons. In Zimbabwe, such collaborations minimised conflicts between cattle owners and non-owners, allowing for draught power sharing and livestock grazing arrangements that helped offset climate-induced constraints (Rufino et al. 2011). Across most of the region, farmers have also responded by seeking off-farm income opportunities. However, these are often restricted to selling of livestock, domestic assets and natural resource-derived products, and temporary migration to urban areas or diasporas (Matiya et al. 2011). Box 1 briefly outlines notable research studies that provide relevant insights on adaptation.

Notwithstanding the above examples, it was generally evident from this review that concrete examples of adaptation by farmers are critically lacking, whether by their mere absence or by lack of research capacity to identify and document them. While a number of adaptation options have been suggested for Southern Africa, including those mentioned above, these have largely been at the research level. There are few, if any, studies clearly documenting adoption of these adaptation options by farmers at scale. Most of the farmers' current responses to climatic shocks have been of a short-term nature, and often punctuated by external but temporal response measures such as food aid and relief programmes.

4.1.5 Lessons from adaptation projects and interventions in the crop farming sector in the region

Major lessons on adaptation in Southern Africa are currently limited to few intervention projects, mainly those conducted under the IDRC-DFID funded CCAA (e.g. Majule et al. 2011; Mapfumo et al. 2010a; Twomlow et al. 2008), DFID (Brown et al. 2012) and the UNDP/Global Environment Facility (GEF) Coping with Drought and Climate Change Projects[7] (e.g. Unganai 2009). The CCAA also supported a project that focused on Building Food Security and Social Resilience to HIV/AIDS. Most other climate change projects have generally been exploratory (assessments), and have largely helped to create awareness among communities and development stakeholders, as well as characterising and developing an understanding of major elements of vulnerability to climate change (e.g. Casale et al. 2010; O'Brien et al. 2009). However, these limited development research studies provide valuable insights and lessons to inform future development planning and policy processes for climate change adaptation in crop-based farming systems. The following are some of the key lessons:

- Adaptive testing of emerging practical options for climate change adaptation at scale in the agricultural sector is increasing necessary, building on available data. Most of the adaptation options suggested for the crop-based farming systems in Southern Africa, such as staggered planting, crop diversification, integrated soil fertility management and irrigation, show promise at experimental scales (Rurinda et al. 2013; Brown et al. 2012; Mapfumo et al. 2010a).

- Food insecurity and poverty are in themselves fundamental sources of vulnerability that will severely limit scope for adaptation. Most smallholder communities typically have limited access to agricultural inputs, soil fertility management technologies, agricultural water, and resource conservation approaches (Mapfumo et al. 2013). This apparently limits their adaptive capacity.

- Farmers, particularly in the smallholder sector, will require technical support to make critical decisions on how to allocate limited resources among crop production, livestock production, natural resources management and off-farm employment (Twomlow et al. 2008; Giller et al. 2006). Detailed studies on trade-off analysis of these production (livelihood) objectives are necessary to inform planning of adaptation interventions at scale, and to guide adaptation policy processes.

- Climate change adaptation research interventions that employ PAR and field-based farmer learning platforms will likely attract effective participation by diverse social groups from among the farmers, including women and the socially disadvantaged (Mapfumo et al. 2013; Mashavave et al. 2013).

- Increasing farmer access to seasonal climate forecasts coupled with technical agricultural information and access to improved seeds, soil fertility technologies and crop production practices will strengthen adaptive capacity of many poor farming communities (Gwandu et al. 2013; Patt et al. 2005).

- Investments into integrated approaches for soil fertility management, soil and water conservation techniques and land reclamation will broaden climate change adaptation options across diverse agro-ecologies and benefit many rural and urban communities in Southern Africa (Tittonell et al. 2012). This could form a basis for participatory development of 'climate smart' crop production options.

- Failures of current development interventions to strengthen local institutions and indigenous knowledge value systems may increase current vulnerabilities and compromise future adaptation processes (Mapfumo et al. 2013; Roncoli et al. 2011).

- There is a general absence of large-scale, well-directed research and development programmes to promote locally-adapted crop types/cultivars/varieties that have traditionally supported livelihoods in Southern Africa.

- Based on available studies, it can be inferred that policymakers must create an enabling environment to support adaptation by increasing access to climate information, credit lines, insurance and markets (input and output) to reach small-scale subsistence farmers with limited resources to confront climate change.

4.1.6 Key documented barriers to adaptation

Major barriers to adaptation processes in Southern Africa revolve around lack of research and development capacity to develop, test and deliver adaptation processes, as well as absence of responsive policies that are specifically tailored to meet the emerging climatic challenges. The launching of CCAA was in recognition of the major gap. UNDP (2008) cited limited on analytical capability of local personnel to effectively analyse the threats and potential impacts of climate change, so as to develop viable adaptation solutions. Thus traditional and contemporary agricultural policy frameworks, developed under these inherent deficiencies, are unlikely to deliver adaptation processes without undergoing substantial changes. For example, with no ready access to good quality seasonal climate forecasts (Mtambanengwe et al. 2012; JIMAT 2008; Patt and Gwata 2002) and knowledge on available adaptation options (Kandlinkar and Risbey 2000), farmers will find it difficult to make decisions and plan against future climate stresses. Agro-ecologies in Southern Africa are generally semi-arid and characterised by poor within season rainfall distribution (Tadross et al. 2009), yet the majority of farmers have no access to conventional forms of insurance. Farmers' perennial problems with lack of timely access to crop production inputs including seed, fertilisers, herbicides, draught power and equipment (Mapfumo et al. 2013; Nyikahadzoi et al. 2012) has largely been attributed to lack of access to lines of credit (Mano and Nhemachena 2007; Nhemachena and Hassan 2007). This is apparently a major disincentive for farmers to invest in organising their local institutions and capacities to demand new knowledge and adopt improved technologies. Instead, poor institutional arrangements and deterioration of social safety nets (Mapfumo et al. 2013; Nyikahadzoi et al. 2012; JIMAT 2008), against a declining resources base, are sinking farmers deeper into a subsistence mode of production and making them more vulnerable. It is, therefore, essential that fundamentals of sustainable crop production and food self-sufficiency be first addressed, in order to reduce risk of external input use and stimulate innovations towards market participation by farmers.

Another hindrance to crop-based adaptation interventions is lack of access to land and poor infrastructure. Poor roads and bridges make access to rural areas difficult, hence compromising delivery of farm inputs (e.g. fertilisers and seeds), access to external learning platforms by farmers, as well as access to markets. This is aggravated by extreme poverty, poor health and malnutrition of vulnerable groups, who are also often illiterate, making it difficult furthermore to build adaptive capacity at the local level. High prevalence of HIV/AIDS puts a major drain on family energy, cash and food (Casale et al. 2010), undermining time and other resource investments (e.g. labour, cash) into food production and pursuance of other livelihood opportunities. Thus failure in other key sectors of rural development will put a strain on climate change adaptation.

4.2 Vulnerability and adaptation of livestock in the region

Livestock production is identified as one of the highly climate sensitive subsectors of agriculture in Southern Africa, yet is an invariably critical source of livelihood for the region's population. In the context of climate change, livestock can be viewed from both mitigation and adaptation perspectives. In the environment, livestock production systems commonly emit carbon dioxide, methane and nitrous oxide gases, cause water depletion and can cause significant soil losses through erosion (Herrero et al. 2009). Mitigation measures could include technical and management options to reduce greenhouse gas emissions from livestock as well as the integration of livestock into broader environmental service approaches (IPCC 2007b). However, due to low input levels in the majority of farming systems in sub-Saharan Africa, the potential contribution of the livestock sub-sector to greenhouse gas emissions is generally considered minimal (ILRI 2009; Herrero et al. 2008). The major focus is therefore on adaptation to support the millions of rural people in Africa, whose livelihoods are closely dependent on livestock.

In its Fourth Assessment Report, the IPCC projected that increased temperatures combined with reduced precipitation in Southern Africa will lead to increased loss of domestic herbivores during extreme events in drought-prone areas (IPCC 2007b). In its regional strategy document, SADC recognised the importance of climate change adaptation initiatives in the livestock sub-sector (SADC 2012). However, clear-cut empirical studies on implications of climate change on livestock in Southern Africa are lacking. An analysis of global livestock systems and livelihoods by ILRI (2009) also revealed that most research on the agricultural impacts of climate change has focused on crops, even in farming systems that contain livestock. Most of the suggested impacts of climate change on livestock have been speculative or drawn from continent-wide analytical frameworks. Key messages can however be drawn from these studies as well as inferred lessons from climate change research conducted in the crop production sub-sector (describe above), with which there are significant overlaps.

4.2.1 Status of scientific evidence for implications of climate change on livestock

The livestock sub-sector will be specifically affected by climate change through effects of changing rainfall patterns and seasonality on feed and fodder production; increase in temperature; reduced water availability; more frequent catastrophic events (e.g. severe droughts); changing patterns and distribution of disease; and increased market volatility. Lack of feed is an inherently critical constraint to livestock production in Southern Africa and crop production is a useful proxy for feed availability. Expected reductions in average crop yield of 10-20 percent by 2050, therefore, have strong implications for livestock feed availability, and there are suggestions that yield losses in some specific agro-ecologies could be worse (Thornton et al. 2007; Jones and Thornton 2003). In Southern Africa, livestock feed is critically short during the long dry months of March/April to October/November. Projected deterioration in rainfall distribution and amounts, coupled to poor and declining soil fertility in both crop and grazing lands is therefore likely to result in severe shortages of common feed resources.

Effects of increased temperatures on water demand by livestock are generally well known in livestock research. In cattle, for instance, the water intake needed for each kilogram of dry matter intake increases from about 3kg at 10°C ambient temperature, to 5kg at 30°C, and to about 10kg at 35°C (NRC 1981). In Southern Africa, the key contribution of groundwater to extensive grazing systems will probably become even more important in the future in the face of climate change. However, the impacts of climate change on water supply changes in livestock systems, such as recharge rates of the aquifers, are still not well known (Masike 2007). On the other hand, shortages in feed resources can have significant impacts on livestock productivity, the carrying capacity of rangelands as well as sustainability ecosystems (Thornton et al. 2007). This will also most likely influence prices of stover and grains, trade in feeds, changes in feeding options, greenhouse gas emissions and grazing management practices (Thornton et al. 2007). There is therefore a high likelihood of increased demand and competition for both water and feed resources within and across communities in many parts of the region.

Serious socio-political and economic conflicts related to livestock grazing and between livestock and wildlife conservancies, as well as land use competition between livestock and crops, are common in Southern Africa (e.g. Andersson et al. 2012; Mutsamba et al. 2012; Roe et al. 2009). Inevitably, major outcomes of such multi-dimensional conflicts will include changes in land use systems. The projected increase in rainfall variability and the expansion of semi-arid agro-ecologies will most likely continue to force farmers out of crop-based production systems due to increased risk of cropping (IUCN 2010). This will have implications on land use changes from mixed crop-livestock systems that are currently dominant in Southern Africa (Dixon et al. 2001) to rangeland based systems (i.e. farmers moving more into pure livestock systems). Such changes will also mean changes in dietary composition of livestock feed and management of feed resources during dry seasons, with possible substantial effects on animal productivity and maintenance of livestock assets (Freeman et al. 2007; Thornton et al. 2007).

Anticipated effects of climate change on livestock are also associated with changes in primary productivity, geographic distribution and feed quality of crops, forages and pastures, influencing availability of feed resources for ruminants. The changes, however, may not always be negative. For instance, it is known that an increase in temperature up to 30-35 °C will result in increased productivity of C4 plants under adequate conditions of water and soil fertility. Such positive effects are attributed to increased rates of photosynthesis and plant growth (Johnson and Thornley 1985). Increases in CO2 levels are also projected to have significant positive effects on productivity of C3 crops and plants providing livestock feed (IPCC 2007a). However, species composition (e.g. proportion of C4 to C3 species, and legumes to grasses) is likely to change depending on agro-ecology and season time (summer or winter), and this may demand changes in grazing management strategies. Other researchers have also suggested that a rise in CO2 levels will also increase the proportion of browse in rangelands due to increased growth and competition of browse species (Morgan et al. 2007; Thornton et al. 2007). Legume species will also benefit from increases in CO2 and therefore the mix between legumes and grasses could be altered. These findings suggest changes in the quality of feed resources with changing climatic factors. With an expected increase in ambient temperatures in Southern Africa, a general increase in lignification of plant tissues is likely, potentially reducing digestibility and rates of degradation of plant species in animals (Minson 1990). This can reduce nutrient availability for animals and reduce milk and meat production, impacting negatively on food security and incomes for smallholders (Delgado 2005; Moorsom and Pfouts 1993). Understanding of the interactions between primary productivity and quality of grasslands/rangelands under increased climate variability and change will therefore underpin development of future adaptation options for the livestock sub-sector in Southern Africa.

Climate change may also impact negatively on livestock reproduction. According to Moorsom and Pfouts (1993), calving rates for cattle can be 60-70 percent in a period of normal rainfall but fall to as low as 25-30 percent in a period of drought. Similarly, normal kidding rate is as high as 160 percent for goats but this rate falls to 50-80 percent during drought periods. Increases in temperatures will result in a decline in dairy production, reduced animal weight gain and reproduction and lower feed conversion efficiency (Cumhur and Malcolm 2008). Dairy production in mixed farming zones is therefore likely to be most affected, since it depends heavily on water supply and quality feed resources (IUCN 2010). These findings suggest a high likelihood of a decline in livestock productivity with the rise in ambient temperature and increased frequency of droughts predicted for Southern Africa by the IPCC models (IPCC 2007b). There are also projections that global warming will alter heat exchange between animals and their environments, potentially jeopardising animal feed intake, growth, reproduction, maintenance and longevity (ILRI 2009). Modelling studies further suggest reduction in animal performance due to decreased forage digestibility.

One of the major influences of climate change on livestock systems in Southern Africa is likely to be associated with changes in epidemiology of both vector-borne and non-vector-borne livestock diseases as habitats for these organisms change. With rainfall projected to decline, frequency of droughts increasing and feed resources diminishing, competition for grazing and water points will most likely increase. This will effectively mean increased concentrations of livestock in specific locations, leading to high chances for disease outbreaks and transmission. Outbreak of the Rift Valley Fever virus in East Africa provides a good example (Seo and Mendelsohn 2008). On the other hand, suitable habitat for Brown Ear Tick (*Rhipicephalus appendiculatus*) is projected to have largely disappeared from its existing range in south-eastern Zimbabwe and southern Mozambique by 2050. This tick caries *Theileria parva*, which causes East Coast Fever in cattle (IUCN 2010; Rogers 1996). The habitat for the Tsetse Fly (*Glossina* spp.) is also projected to decrease, and this will effectively reduce the risk of trypanosomiasis, one of the diseases that severely limit livestock production in Africa (Thornton et al. 2008). There are therefore prospects for possible expansion of livestock areas in Southern Africa, although potential interactions with water and feed availability remain unknown.

4.2.2 Causes of vulnerability in livestock systems in Southern Africa

Because of strong crop-livestock interactions in Southern Africa, the major causes of vulnerability discussed for cropping systems under section 4.1.2 are also applicable to livestock. However, there are sources of vulnerability that are specifically relevant to communities whose livelihoods are dependent more on livestock than cropping (IUCN 2010; Thornton et al. 2006). This is particularly true for communities in the semi-arid areas of Southern Africa, and the major causes revolve around the following:

i) *Increasing human population pressure on land and other natural resources:* This is linked to both internal demographic growth factors and influx of people from external sources seeking new economic opportunities through agriculture (e.g. 'land grabbing' by large multinational agricultural companies), tourism and wildlife conservation (e.g. establishment of mega Transfrontier Wildlife Parks in Southern Africa). With such emerging interventions there are threats of livestock being squeezed out of the agricultural systems. This will eliminate a major source of livelihood for many households and communities, yet current studies (e.g. Andersson et al. 2012) reveal that the benefits of such mega-interventions tend to bypass the local (poor) communities.

ii) *Over-dependence of the region's livestock production systems on natural water and feed resources that are in turn climate sensitive:* Diminishing feed resources from both croplands and grazing areas due to poor and declining soil fertility and variable climatic factors poses major threats. Famers often face problems in managing trade-offs between livestock management and other livelihood options for which there is competition of resource use. Several research studies have revealed inefficiencies related to allocation and management of resources to sustain productivity of these complex systems (Giller et al. 2006; Rufino et al. 2006; Delve et al. 2001).

iii) *Land degradation and desertification:* In as much as livestock production is in itself a major cause of land degradation due to overstocking and/or low carrying capacity of grazing lands, the impacts on livelihoods of agro-pastoral communities are huge. Land degradation reduces carrying capacity and there is no empirical evidence on how this will likely interact with climate change and variability. However, emerging research innovations focusing on pathways for restoration of degraded croplands and intensification of crop-livestock systems (Rusinamhodzi et al. 2013; Tittonell and Giller 2012; Nezomba et al. 2010; Mapfumo et al. 2005) are likely to provide major insights on climate change adaptation options.

iv) *Diminishing relevance of current institutions and governance structures in the wake of climate change and variability:* Strong interdependencies between crop production and livestock (soil fertility management, draught power provision, crop-derived feed resources, socio-cultural values of livestock) have given rise to complex institutions and governance systems that have sustained these mixed/agro-pastoral systems to date. However, new forms of institutional arrangements and governance structures required to enable adaptation processes against the pending impacts of climate change and variability remain largely unknown, as new forms of economic development such as eco-tourism, wildlife conservation and mining increasingly interface with livestock systems.

v) *Lack of access to improved livestock production technologies, including poor access to livestock veterinary services:* Farmers often have limited access to new knowledge on production technologies and lines of credit (Thornton et al. 2006), reducing their competitiveness on national and regional markets. The problem is linked to a weak regional focus on transforming the predominantly smallholder livestock production systems out of subsistence into market oriented farm enterprises. This is despite the growing demand for livestock products from rising urban markets. While the recent SADC regional policy framework prioritises this area (SADC 2012), there is apparently a limited body of scientific knowledge in the region to inform such a transformation.

4.2.3 Options for strengthening adaptive capacity of livestock systems to climate change

As with the cropping sub-sector, options for building adaptive capacity of livestock systems are likely to be those rooted in local knowledge systems and institutions and operational at different scales (e.g. field, farm, community, national) to address interactions among the multiple factors regulating food security, environmental services and livelihoods. According to Thornton et al. (2008), farmers require secure land rights, strong and equitable local institutions and functioning legal systems at the local scale. Five broad areas around which adaptive capacity can be strengthened in livestock systems were suggested by ILRI (2009), and can be modified on the basis of various other related studies (Brown et al. 2012; IUCN 2010; Government of Zimbabwe/UNDP/GEF 2009; Herrero et al. 2009; Thornton et al. 2009; Chilonda et al. 2007):

i) *Supporting adaptation actions at the local level:* This essentially involves strengthening crop-livestock integration (e.g. improving efficiencies at scales) and promoting diversification of livestock production systems (and also associated cropping systems), including reducing over-dependence on cattle in certain agro-ecologies and adopting stress-tolerant livestock types.

ii) *Reducing risks in livestock production systems:* Development of institutional and policy frameworks allowing access to insurance and lines of credit to livestock farmers is likely to encourage farmers to adopt improved production technologies and management practices, but also to participate in markets.

iii) *Institutional adaptation:* Empowering farmers to self-organise, draw on their local knowledge systems and participate in local, national and regional markets can encourage farmers to make appropriate marketing decisions in response to climate early warnings (prospects of hydrological droughts, reduction in seasonal feed availability, etc.).

iv) *Technological adaptation:* Develop capacity for farmers and service providers to develop and/or adopt new methods, tools and technologies with communities to realise new livestock breeds, develop new types of feed resources and associated feeding strategies, and address new challenges in soil and water management (e.g. adoption of irrigated pasture systems, adapting CA options) and animal health.

v) *Promoting participatory action research and co-learning processes in the livestock production systems:* These provide possible pathways for influencing attitude and behaviour of farmers and stakeholders towards ownership of the change processes that favour adaptation.

4.2.4 Documented adaptation by farmers in the region and lessons learnt from project interventions in livestock

Comprehensive empirical studies documenting adaptation options in the livestock sub-sector are generally absent in Southern Africa. Farmers have responded to droughts and poor rainfall seasons through selling of animals and/or buying fodder for their livestock (Murungweni et al. 2011). Large scale farmers have often managed to adjust stocking rates by selling off their animals at younger ages, as well as resorting to heat tolerant breeds (Benhin 2006; Hudson 2002). On the other hand, increased frequency of severe droughts in southeast Zimbabwe led to farmers exploring unusual alternative feed resources, discovering a leguminous shrub, *Neorautanenia brachypus* (Harms) C.A.Sm., as an important medicinal feed that they now use to help cattle survive drought (Murungweni et al. 2012). Zimbabwe lost 23 percent of the national herd during one of Southern Africa's worst droughts between 1991 and 1992, and the southeast lowveld was one of the most affected areas.

Results of the study by Murungweni et al. (2012) showed that *N. brachypus* was used by 59 percent of cattle owners during drought, while 14.5 percent of the farmers were non-users because they had alternative grazing, and a further 26.5 percent had no knowledge of it. A joint project of the Government of Zimbabwe, UNDP and GEF entitled Coping with Drought and Climate Change, implemented in the same area, showed that management of water and feed resources during drought years is a major challenge for most communities (Government of Zimbabwe/UNDP/GEF 2009). Communities in the study area prioritised the introduction of new mixes of livestock breeds as an adaptation strategy. Management and conservation of fodder and water were also prioritised. While farmers are also known to migrate their livestock to other locations across communities to access better feed resources, it was apparent that farmers would only sell their livestock (particularly cattle) in exceptionally difficult circumstances (Milgroom and Giller 2013). Key lessons from these limited studies are that farmers will need to consider new sources of livestock feed resources, and that lack of water resources narrows their adaptation options.

4.2.5 Documented barriers to adaptation

Lack of access to information is reported as a major constraint. This is often linked to cases of illiteracy, as well as general absence of knowledge sharing platforms. Studies by Gwandu et al. (2013) from eastern Zimbabwe showed how organisation of farmers into learning alliances can enhance participation in adaptation processes by diverse social groups within and across communities, including women farmers. Murungweni et al. (2012) found that more than 25 percent of the surveyed households in southeast Zimbabwe could not use a locally discovered feed resource simply because they had not heard about it, despite living within the same community. Challenges related to access to information by farmers have been considered as particularly critical for weather forecasts (Ziervogel and Calder 2003; Patt and Gwata 2002). Insecure land tenure systems and weakening or breakdown of customary governance institutions have also been identified as a major barrier in livestock systems, including inequities in the global livestock trade (IUCN 2010). These factors add to those that are equally applicable to crop-based farming systems. Overall, the case of livestock in Southern Africa presents a paradox for research: there are clear indications that farmers increasingly consider cropping as risky and are therefore increasingly moving into livestock (Chilonda et al. 2007); yet the livestock subsector presents a smaller knowledge base on climate change adaptation.

4.3 Vulnerability and adaptation of fisheries in Southern Africa

Global perspectives based on IPCC projections are that anticipated climate change and variability impacts on fisheries will include falling productivity, species migration and localised extinctions (IPCC 2007a). This is likely to give rise to conflict over use of scarce resources, although communities may also benefit from expanded areas where aquaculture becomes viable due to favourable temperatures and rising sea levels in coastal areas. However, reduced water availability and quality, increased disease incidence and problems with salinisation of groundwater may present major challenges (Allison et al. 2007). Southern Africa has large stretches of coastal waters, mainly in Mozambique, Namibia and South Africa, while most of the other countries such as Botswana, Malawi, Zambia and Zimbabwe are landlocked, but with sizable communities that draw livelihoods from fishing activities on inland freshwater lakes, dams and rivers. Current and potential impacts of climate change and variability on fisheries are here discussed with a specific focus on Malawi, South Africa and Zimbabwe.

4.3.1 Status of scientific evidence for implications of climate change on fisheries

A predicted decline in rainfall in Southern Africa against increased temperatures, rise in evaporation rates and increased demand for irrigation water is expected to decrease runoff by 10-30 percent (IPCC 2007a). This is expected to cause a decline in fish stocks. Reduced dry season flow rates predicted for the region's river basins are also expected to impact negatively on spawning and larval dispersion, resulting in reduced fish yields (FAO 2007). An increase in temperature often reduces availability of wild fish stocks in land water by negatively affecting water quality, worsening dry season mortality, bringing new predators and pathogens, and changing the abundance of food available to fishery species (Allison et al. 2007). In South Africa, there are indications of damaged coral reefs due to rising water temperatures and ocean acidification (Nicholls et al. 2007). When sea temperatures exceed long-term summer averages by 1°C, coral reefs suffer 'bleaching', rejecting the colourful algae with which they normally have a symbiotic relationship, resulting in loss of colour, greater exposure to disease and often death (Nicholls et al. 2007). This has serious negative effects on coastal reef fisheries, and also poses a health hazard by potentially exposing people to a form of poisoning known as ciguatera, which occurs when ones eats fish grazing on toxic algae growing on dead coral reefs (IPCC 2007a). The coastal zones of South Africa are also expected to experience increased average sea surface temperatures and intensified extreme weather events, potentially including a stronger and more prolonged El Niño (Nicholls et al. 2007). Continued increases in ocean acidification have also been reported (Dulvy et al. 2010; IPCC 2007b).

Measured climatic impacts on Malawi's two major lakes, Lake Malawi and Lake Chilwa, and Zimbabwe's man-made Lake Kariba present some interesting case studies. Temperature increases as high as 0.2-0.7°C have been recorded in Lake Malawi's deep waters over the past 100 years (Rosenzweig et al. 2007). This warming has resulted in an increase in thermal stratification, a reduced mixing of cold deep and warm surface waters. This resultant warming also prevents upwelling of nutrients, and in turn reduces primary productivity (Rosenzweig et al. 2007). Decline in rainfall and an increase in air temperature also threaten the production of fisheries in the lake (Allison et al. 2007). In Lake Malawi and Lake Chilwa, there is reduced primary productivity due to a sharpened water density gradient between warmer surface water and cooler deep water, which has slowed vertical mixing. Due to lower wind speeds, there has been reduced mixing in the lakes and primary productivity may have decreased by about 20 percent, accounting for a roughly 30 percent decrease in fish yields (Allison et al. 2007). Unlike Lake Malawi, Lake Chilwa is known to average only 3m in depth and can dry out completely when annual rainfall is low. However, in years of high rainfall it supplies up to 25 percent of Malawi's fish and employs 10,000 people (FAO 2007). Stock levels in the lake are determined largely by variable water levels, making conservation efforts difficult and subject to seasonal climatic factors, particularly rainfall and temperature. According to Allison et al. (2007), wetlands serve a critical role by providing refuge to fish during periods of drought when the lake is dry. Maintenance of these wetlands is therefore a critical activity for sustainability of the fisheries and benefits they bring to the predominantly poor communities.

Zimbabwe's biggest water body, Lake Kariba, is estimated to have warmed by about 2°C since 1964, with maximum air temperatures around the lake having been rising at a faster rate than the minimum temperatures (Magadza 2011; Desanker and Magadza 2001). Consequently, a significant decline in zooplankton population has been reported, while cyanophyceae, particularly *Cylindrospermum raciborskii*, have been found to dominate the lake phytoplankton. This has resulted in a decline in pelagic fish due to reduced food availability arising from a reduced phototrophic zone depth, as well as low nutrient recharge caused by reduced water mixing (Magadza 2011; Desanker and Magadza 2001; Chifamba 2000). Rainfall around the lake area has decreased at a rate of 0.63mm per year since 1963, with evaporation rates increasing by 31 percent. Based on an analysis by Ndebele-Murisa et al. (2011), a major consequence has been a significant decrease in Kapenta (*Limnothrissa miodon* and *Stolothrissa tanganicae*) fish production at a rate of 24t/year since 1974. Artisanal fish catches were also found to decline at an average rate of 37t/year between 1974 and 2003. The variations in the Kapenta fish catches were most significantly influenced by the lake's water levels, followed by maximum temperature, evaporation and rainfall (Ndebele-Murisa et al. 2011). These finding suggest that local-level climatic effects could already be impacting significantly on ecosystem components that currently underpin livelihood activities of poor communities in these countries.

4.3.2 Causes of vulnerability

Mozambique, Malawi, Zambia and Zimbabwe are ranked among the world's top twenty national economies most vulnerable to the impacts of climate change and variability on fisheries and aquaculture (Allison et al. 2009). Mozambique is the highest ranked (#13), while Malawi and Zimbabwe are ranked #15 and #17 respectively. The major causes of vulnerability for communities dependent on fisheries and aquaculture include the following:

i) Increasingly receding water levels due to a decline in recharge and high evapotranspiration losses (Allison et al. 2007; 2005). The predicted increases in air temperature and consequent warming of surface water will aggravate these conditions, resulting in declining fish stocks/yields.

ii) Increased variability in rainfall within and across seasons with occurrences of extreme droughts and floods.

iii) High dependence on fish protein in diets of communities. There are limited sources of protein in cereal-based farming systems of Southern Africa, particularly in Malawi where livestock farming is relatively low.

iv) High dependence on fisheries as the main source of livelihood, with limited alternative sources of both food and employment (WorldFish Center 2009).

v) High levels of poverty and food insecurity, constraining communities in taking advantage of emerging livelihood opportunities or investing in adaptation processes. Communities have no access to financial support such as lines of credit, limiting opportunities for growth of the sub-sector.

vi) Weakening institutional arrangements to regulate access to the shrinking resource base, often discriminating against disadvantaged social groups.

However, interactions of fisheries and other agricultural sub-sectors, and how these may change with increased climate variability and change, have largely remained unknown. This may, therefore, limit the scope for development planning on adaptation options.

4.3.3 Documented adaptation by fisheries systems in Southern Africa

Most of the documented coping strategies and emerging adaptation options have come out of Malawian communities whose livelihoods are heavily depended on fishing in Lake Malawi and Lake Chilwa. Most of the households have switched between fishing and smallholder farming depending on variations in fish availability within and between seasons. Wetlands on the fringes of lakes have often been converted to production of crops that include rice, cassava and vegetables (Allison et al. 2007). Some of the households have also migrated to new locations, including movements to other lakes, depending on fish availability. This includes drastic reductions in fishing activities by communities who restrict themselves to any remaining swamps and streams during drought years. Diversification into other livelihood options has also been used as an adaptation measure. Common alternative livelihood sources include commercial handicrafts, trading, wage labour and casual labour (Jul-Larsen et al. 2003; Allison et al. 2000; Sarch and Allison 2000). Research in Malawi has also shown success of options that integrated pond aquaculture with traditional crops in reducing farmers' vulnerability to drought and providing a high-quality protein source (Jamu and Chimatiro 2004). The WorldFish Center has since recommended integration of pond aquaculture into smallholder farming systems (WorldFish Center 2007) to reduce vulnerability of poor communities.

4.3.4 Options for strengthening adaptive capacity of fishery systems to climate change

Problems facing fisheries in Southern Africa are basically a problem of the commons in a context of poverty. Many poor communities draw their livelihoods from fisheries the same way they do from woodlands and rangelands in their environments. The major institutional, management and policy challenges facing these sub-sectors are therefore similar or closely related. Potential options for strengthening adaptive capacity of communities dependent on fisheries are therefore likely to hinge on principles of participatory action learning and research that inform processes of community-based natural resources management and farmers' growing livelihood demands. Based on findings and insights from different studies (FAO 2008; Word Bank 2005; Allison and Mvula 2002; Allison and Ellis 2001; IFRC 2001), the following options are considered applicable:

i) Build research and extension expertise and capacity to understand the underlying ecological systems determining sustainability of fisheries, as well as how they currently interact with farmers' livelihoods and coping strategies in response to increased climate variability and other multiple stresses.

ii) Promote diversified and flexible livelihood systems that build on local institutions but enable different social groups to adopt new knowledge on methods, tools and technologies in the management of fisheries. This includes provision of financial support and training for communities and their service providers (e.g. extension agents) to access and use new equipment and employ new approaches.

iii) Develop and implement policy frameworks that promote co-management approaches and enhance ownership of resource management processes and benefits by local communities. Apparently, existing policies tended to discriminate against local communities with respect to mainstream economic activities around fisheries. Key elements for suggested policy framework could include: integration of land and water resource tenure; supporting local governance structures and removing current barriers to management of common property resource pools during times of scarcity and crisis; and supporting reciprocal resource access arrangements (Allison and Ellis 2001) as a mechanism to reduce conflicts related to resource access. Such co-management approaches are likely to contribute towards addressing problems of overfishing and pollution against changing hydrological conditions.

iv) Building the capacity of communities to shift towards aquaculture to reduce the high water requirements of natural fisheries and to integrate fisheries with other farm activities. The integration is likely to enhance productivity of water use and efficiency of nutrient cycling within farms.

v) Support development of technological and market innovations such as selective fish breeding to develop fish that have different thermal optima, growth characteristics, feed conversion efficiencies and disease tolerances; and improved storage such as refrigeration and post-harvest handling and processing, which can reduce losses due to deterioration of fish quality.

vi) Establishment of surveillance and early warning systems that enable timely access to seasonal weather forecasts and market information by communities.

vii) Support initiatives to reduce fishing efforts in overexploited fisheries, as lightly-fished stocks are likely to be more resilient to climate change impacts than heavily-fished ones (Allison et al. 2002).

Promotion of cross-boundary cooperation and flexibility of regional fishing agreements to cope with shifting stocks, as well as integration of fisheries and aquaculture into other national policies on climate change, food security and water management (Brander 2007), can also provide a conducive environment for building adaptive capacity in fishery systems.

4.3.5 Documented barriers to adaptation

The current and potential role of inland fisheries in livelihoods of poor communities in Southern Africa has generally been diminished by continued threats of land degradation and destruction of catchments of major rivers and water bodies. Any future decline in rainfall as currently projected (IPCC 2007b) will further compromise the functioning of the aquatic ecosystems and greatly reduce the relevance of fisheries to the livelihoods of many poor communities. Major lessons on barriers for climate change adaptation in fishery systems can be drawn from Malawi, where conflicts and power struggles typically exist between local elites and the poor local communities, and between migrant and resident fishers (Allison et al. 2007). Key barriers include:

i) Failures of state regulatory instruments, particularly relating to failure by the state to control use of destructive fishing methods, and abuse of political power resulting in restriction of access to fisheries by certain ethnic groups (Hara et al. 2002).

ii) Pollution of major water bodies, exacerbated by rising urban populations, which may greatly compromise the functioning of aquatic ecosystems with negative consequences on fisheries. However, the interaction of these emerging factors with climate change, and subsequent effects on fisheries and alternative adaptation options, are still unknown.

iii) Inherent food security challenges with limited alternative sources of food and employment for most small-scale and migrant fishing communities in poor countries (WorldFish Center 2009).

iv) Lack of savings, credit facilities and infrastructure (Allison et al. 2005; 2007).

v) High prevalence of HIV/AIDS among fishing communities, a problem which may be aggravated by climate change-induced migrations and social dislocation (Allison et al. 2005).

vi) Lack of policy incentives for diversification out of fisheries in poor communities. Poverty in itself is currently a major impediment to climate change adaptation by fishing communities (World Bank 2008; Ellis et al. 2003).

The barriers discussed above are better understood in the context of the broader challenges to sustainable livelihoods in the predominantly smallholder agricultural sector of Southern Africa.

5 Agricultural policies for climate change adaptation

5.1 State of knowledge on policies and strategies for climate change adaptation in the agricultural sector

In all the three focus countries for this study, the major policy and strategic considerations for climate change adaptation are variably contained or implicitly implied within and outside agricultural policy frameworks. However, there is a clear reflection that the major national policy documents are informed by the international and regional conventions and discourse on climate change, particularly those derived from UNFCCC, NEPAD and SADC.

5.1.1 Climate change considerations in national agriculture sector policies and strategies

In Malawi, climate change adaptation is covered in several government agricultural policy and strategy documents including the Food Security Policy 2006, National Agricultural Policy (2010-16), Agriculture Sector Wide Approach (ASWAp) of 2010, National Water Policy (revised 2005), National Disaster Risk Management Policy, National Land Resources Management Policy and Strategy and National Irrigation Policy and Development Strategy of 2000 among others (CEPA 2012; Government of Malawi 2011; 2006). Out of these documents, the National Agricultural Policy, which is mirrored by the ASWAp, explicitly provides action points for climate change adaptation. The ASWAp is a response to Millennium Development Goal 1 and to CAADP Pillars 1 and 2 (Government of Malawi 2011). It broadly focuses on agricultural growth and poverty reduction, but specifically addresses food security and risk management and sustainable land and water management. It is thus consistent with the National Agricultural Policy, which provides for the specific actions in relation to climate change adaptation:

i) Improving vulnerability assessments to provide early warning on food security. The ASWAp goes on to highlight a need for insurance against weather.

ii) Enhancing food security and developing community-based seed and food storage systems.

iii) Improving crop and livestock production through the use of appropriate technologies. The ASWAp emphasises use of improved crop varieties and livestock breeds that are tolerant to drought, and developing/implementing strategies for drought preparedness.

iv) Increasing resilience of food production systems to erratic rains by promoting sustainable dimba production of maize and vegetables in dambos, wetlands and along river valleys. In this regard, the ASWAp emphasises protection of catchment areas and fragile areas including wetlands and rivers, as well as increased use of irrigation and development of small dams for water harvesting.

v) Developing a framework to ensure that all agriculture projects and programmes undertaken in the sector have had environmental impact assessments as required by the Environment Management Policy and Act and the related international instruments.

vi) Mainstreaming gender and HIV/AIDS issues.

vii) Strengthening the capacity of all stakeholders in issues of mainstreaming environmental management in the agricultural sector.

The National Water Policy focuses on water resources management and development and recognises the increasing incidence of droughts and floods. It calls for good catchment management to maintain/enhance ecosystems functioning and preserve biodiversity, including protection of wetlands. The National Irrigation Policy and Development Strategy focuses on irrigation development to reduce dependence on rain-fed agriculture. However, it does not recognise potential negative impacts of climate change variability on irrigation development. It explicitly calls for measure to reduce impacts of climate change to minimise economic and cultural disruptions and dislocations of the most vulnerable people. Other documents, such as the Policy Document on Livestock in Malawi and the National Gender Policy of 2000, do not offer clear action points on adaptation, although the latter recognises women as one of the most vulnerable groups to climate change and variability.

South Africa provides some of the major contrasts in agricultural policies and strategies on climate change adaptation, most likely due to the relatively low contribution of agriculture in the country to national GDP and therefore a different focus on major pathways to economic development. The key guiding policies and strategies for agriculture in South Africa are contained in the Integrated Growth and Development Plan 2012 (Government of South Africa 2012). The document responds to the country's macro-economic Medium Term Strategic Framework by addressing three of the 12 targeted outcomes: to achieve decent employment through inclusive economic growth; to have vibrant, equitable and sustainable rural communities contributing towards food security for all; and to protect and enhance the country's environmental assets and natural resources. The policy document recognises the critical challenges of climate change, and clearly embraces the need for substantial public and private investments in irrigation; support of crop varieties and animal breeds that are tolerant to heat, water and low soil fertility stresses; and imperative to build roads and marketing infrastructure to improve small farmers' access to critical inputs as well as to output markets. The policy framework also dovetails well with the Comprehensive Rural Development Programme (CRDP) of the Department of Rural Development and Land Reform (DRDLR). The CRDP focuses on three main pillars, namely land reform, agrarian transformation and rural development (Government of South Africa 2009). The CRDP addresses several critical developmental issues that focus on reducing vulnerabilities of the socially diverse rural communities, and is therefore relevant for enhancing climate change adaptation processes. These include:

i) The empowerment of rural communities, especially women and the youth, through facilitating and mediating strong organisational and institutional capabilities and abilities to take full charge of their collective destiny.

ii) Capacity building initiatives, in which rural communities are trained in technical skills, combining them with indigenous knowledge to mitigate community vulnerability to, especially climate change, soil erosion, adverse weather conditions and natural disasters, hunger and food insecurity.

iii) The establishment of business initiatives, agro-industries, cooperatives, cultural initiatives and vibrant local markets in rural settings.

iv) Revitalisation and revamping of old, and the creation of new economic, social and information communication infrastructure and public amenities and facilities in villages and small rural towns.

v) Empowerment of rural communities to be self-reliant and able to take charge of their own resources.

vi) Development of mitigation and adaptation strategies to reduce vulnerabilities with special reference to climate change, erosion, flooding and other natural disasters.

vii) Increased production and sustainable use of natural resources, including related value chain development in livestock (exploring all possible species for food and economic activity) and crop farming (exploring all possible species, especially indigenous plants, for food and economic activity).

The above policy and strategy documents evidently build on the Integrated Food Security Strategy for South Africa (Government of South Africa 2002), which was launched with the overarching objective to eradicate hunger, malnutrition and food insecurity by 2015. Some of the key specific objectives of the strategy were to:

a) Increase household food production and trading.

b) Improve income generation and job creation opportunities.

c) Improve nutrition and food safety.

d) Increase safety nets and food emergency management systems.

e) Improve analysis and information management system.

f) Provide capacity building.

The strategy involved a wide range of interventions that included food production, infrastructure development, storage and transportation of food, social security grants, food emergencies and micro financing. However, lessons drawn from the initiatives and their contributions to climate change adaptation thus far have not been clearly reflected in the new policy documents.

In Zimbabwe, the agriculture sector policies and strategies are provided for in the Comprehensive Agriculture Policy Framework 2012-2032 (Government of Zimbabwe 2012a), which supersedes the Zimbabwe Agricultural Policy Framework 1995-2020, which was rendered non-functional by the government's land reform programme of 2000. The new policy framework was necessitated by the need to address the country's new challenges and opportunities in the agricultural sector, in line with the national macro-economic policy contained in the Zimbabwe Medium Term Plan 2011-2015. The major policy objectives as outline in the document include:

- Assure national and household food and nutritional security.
- Ensure that the existing agricultural resource base is maintained and improved.
- Generate income and employment to feasible optimum levels.
- Increase agriculture's contribution to gross domestic product.
- Contribute to sustainable industrial development through home-grown agricultural raw materials.
- Expand significantly the sector's contribution to the national balance of payment.

Surprisingly, the policy framework is largely silent on climate change, and does not put any emphasis on specific challenges related to rainfall variability, increasing temperatures and frequent droughts and occasional floods affecting the sector. This is despite the apparent recognition by the government of the high vulnerability of this national livelihood pillar to the pending negative impacts of climate change and variability. Climate change is only mentioned explicitly under crop diversification, with a specific focus on breeding of drought tolerant crops, apparently offering a limited scope for adaptation. This implies that climate change adaptation is not considered a development issue within the agricultural sector. However, a National Policy and Programme for Drought Mitigation is also in place, which provides for provincial and district programmes to access funding from international organisations for purposes of drought mitigation. The policy framework has also guided the establishment of regional early warning systems and drought monitoring centres (Chagutah 2010). The country's National Water and National Irrigation Policies, along with a number of other policies, are also under development as the country recovers from more than a decade of socio-political and economic crisis. These emerging policies offer opportunities for addressing some of the deficiencies on climate change adaptation in the new agricultural sector policy document.

5.1.2 Climate change considerations in regional agriculture sector policies and strategies

All countries in Southern Africa are members of the African Union and SADC. Malawi, South Africa and Zimbabwe are therefore all signatories to major regional treaties and protocols that guide economic development to safeguard natural resources and the environment for the benefit of the region's diverse populations. One of the African Union's major development initiatives is NEPAD (AU/NEPAD 2003), and all the countries subscribe to its programmes. Particularly relevant to the regional agriculture sector is CAADP, which implicitly embraces climate change issues under its strategic Pillars 1 and 3.[8] Pillar 1 of CAADP seeks to extend the area under sustainable land management and reliable water control systems. Pillar 3, on the other hand, aims to increase food supply and reduce hunger across the region by raising smallholder productivity and improving responses to food emergencies. While the two pillars strategically address some of the fundamental sources of vulnerability to climate change and vulnerability by communities in Southern Africa, their design formulation was apparently not from a climate change adaptation perspective. CAADP is also consistent with the joint efforts of the European Union member states to fulfil the United Nations' Millennium Development Goals.

SADC has developed a Regional Agricultural Policy (RAP) (SADC 2012) which seeks to harmonise policy for agriculture and natural resources and strengthen the interventions so far guided by the SADC Regional Indicative Strategic Development Plan (RISDP) of 2003. One of the major areas of focus for the RAP is to reduce vulnerability in its broad sense. The policy document specifically identifies the regional agriculture sector as vulnerable to climate change and variability, and recognises the critical need for adaptation. The policy also draws on the momentum of earlier protocols on agriculture, although these are not explicit on how to address climate change adaptation challenges. These include:

- The SADC Dar es Salaam Declaration on Agriculture and Food Security of 2004, which prioritised sustainable food security as well as environment and sustainable development.

- The SADC Maputo Declaration of 2003, which required countries to commit at least ten percent of their national budgets to agriculture.

- The Maseru Protocol of 1996 (eventually launched in 2008), which sought to establish a SADC Free Trade Area to enable member states to liberalise trade through removal of tariffs and non-tariff barriers. South Africa is one of the countries that have fully implemented this Trade Protocol, allowing 99 percent of imports from within SADC to enter the South African market free of customs duties (Government of South Africa 2012).

These regional protocols and policy strategies offer opportunities to broaden the scope for climate change adaptation and draw on integration of major adaptation processes that may be warranted at the trans-border and regional scales.

The Common Market for Eastern and Southern Africa (COMESA), to which Malawi and Zimbabwe, but not South Africa, are members, is a regional organisation with a principal focus on agricultural development as a means for achieving economic growth, industrial take-off, agricultural trade and employment creation. In 2002, the organisation passed a COMESA Agricultural Policy aimed at harmonising national policies of member states towards a COMESA Free Trade Area FTA. Subsequently, the COMESA Nairobi Declaration of 2004 on Expanding Opportunities for Agricultural Production, Enhanced Regional Food Security, Increased Regional Trade and Expanded Agro-Exports through Research, Value Addition and Trade Facilitation was a milestone in pursuance of regional integration. Positive outcomes of these policy initiatives include the Maize Without Borders Policy Platform. The COMESA policy initiatives may offer a conducive policy environment for broad-based climate change adaptation and disaster risk reduction management interventions in the region.

5.1.3 Agriculture considerations in climate change policies and strategies

The development of climate change policies and strategies by national governments in Southern Africa is essentially work in progress, as both awareness and understanding of processes is still gathering momentum, courtesy of the UNFCCC processes. Malawi and South Africa have already completed development of their climate change response policies and strategies. The national strategy for Zimbabwe is under preparation. A National Climate Change Office has been established under the Ministry of Environment and Natural Resources. A national inter-ministerial taskforce on climate change was also formed. Invariably across the three countries, the climate change policies and strategies are housed in the national ministries of environment.

The Government of Malawi, through the Environmental Affairs Department of the Ministry Of Environment and Climate Change Management, launched its National Climate Change Policy in 2012 (Government of Malawi 2012) with the objective to 'reduce vulnerabilities and promote community and ecosystem resilience to the impacts of climate change'. Climate change adaption is ranked first out of eight key priority areas. The Malawi National Adaptation Programme of Action (NAPA) of 2006 (Government of Malawi 2006), which was developed as part of the UNFCCC process, is embraced by the new policy. All five prioritised adaptation options under the NAPA are strongly related to agriculture and aimed at increasing resilience of vulnerable communities to climate-related risks and disasters:

i) Improving community resilience to climate change through the development of sustainable rural livelihoods.

ii) Restoring forest in Upper, Middle and Lower Shire Valleys catchments to reduce siltation and the associated water flow problems.

iii) Improving agricultural production under erratic rains and changing climatic conditions.

iv) Improving Malawi's preparedness to cope with droughts and floods.

v) Improving climate monitoring to enhance Malawi's early warning capability and decision-making and sustainable utilisation of Lake Malawi and lakeshore areas resources.

However, lack of funding has been a major constraint to implementation of the Malawi NAPA, at least up to 2013. The National Disaster Risk Reduction Framework of 2010 provides for strengthening of early warning systems, addressing a critical area for development processes in agriculture.

In South Africa, the National Climate Change Response Strategy was developed in 2004, with the main objective to 'support the policies and principles laid out in the Government White Paper on Integrated Pollution and Waste Management, as well as other national policies including those relating to energy, agriculture and water' (Government of South Africa 2004). The strategy recognises the vulnerability of the agricultural sector, including rangelands, forests, fisheries and crop-livestock systems. The document also puts significant emphasis on mitigation. Unlike in Malawi, where adaptation in the agricultural sector is an obvious priority area, the sector is apparently not as emphasised in South Africa. This is most likely due to the relatively low contribution of agriculture to the national GDP.

5.2 Review of key arguments for policies on adaptation to climate change in the agricultural sector

The major calls for supportive policies on climate change adaptation in the agricultural sector in Southern Africa arise from the increasing realisation of the threats to food security at household and national levels, supply of industrial raw materials and national employment. This is particularly critical for countries such as Malawi and Zimbabwe, where the livelihoods for the majority of national population are dependent on rain-fed agricultural systems (e.g. Government of Malawi 2012; Government of Zimbabwe 2012a; Chilonda et al. 2007). Consistent with CAADP and the strategic policy objectives of SADC and COMESA, agriculture is viewed as the main vehicle for economic growth in Malawi and Zimbabwe, where the national agricultural policy frameworks deliberately seek to enhance its contribution to GDP. Although South Africa's agriculture, forestry and fisheries sector constitutes a small proportion of the national GDP (around three percent), the government still recognises its critical role in national and household-level food security; ensuring social and economic growth and development through job creation; and contributing to rural socio-economic development, particularly among the country's rural communities (Government of South Africa 2012). For example, about 70 percent of total grain production in South Africa consists of maize, a climate sensitive crop in the context of Southern Africa. Predictions of yield declines in excess of 20 percent will therefore have a significant negative impact on the country's rural poor. There are also fears that any changes in rainfall and temperature may cause significant changes in areas uniquely suitable for specialised production of cash crops for export (Government of South Africa 2004).

5.3 Review of key policy actors and networks involved with adaptation to climate change in the agricultural sector

The majority of policy related interventions on climate change adaptation in Southern Africa have been at a research level, out of which fewer than 50 percent have focused on policy in a significant way. However, there has been significant involvement of development partners, NGOs, international research organisations and regional policy networks in many of the research projects (Table1), providing leveraging for possible policy advocacy and dialogue processes. However, the total number of completed and ongoing projects for which there is published evidence is very small in relation to the magnitude of the problem. Most of the policy-related projects have also focused mainly on awareness raising (Table 1), most likely because of lack of empirical evidence at the local level.

Table 1: State of knowledge on stakeholder involvement on adaptation to climate change in the agricultural sector in Southern Africa

Country	Stakeholders	Category	Work done	Reference
Zimbabwe	Lutheran Development Services (LDS)	Research/ Policy	• Building adaptive capacity and sustainable livelihoods of smallholders in Makuwerere Ward, Mberengwa through gulley reclamation, conservation farming and documentation of climate change initiatives and policy recommendations related to climate change.	Brown et al. 2012
Zimbabwe	SOFECSA	Research	• Learning Centre concept (farmers self-mobilise and come up with technologies to adapt to climate change, e.g. staggering of crops, growing of small grains and different crop varieties). • *Zundera Mambo* concept (social safety net): chief supports communal production of staple maize and maintains a strategic grain reserve for the disadvantaged during years of crop failure.	Mapfumo et al. 2013
Zimbabwe	Department of Meteorological Services; FAO	Research	• Mid-term forecasting and provision of forecast information to smallholder farmers.	Chikoore and Unganai 2001
Zimbabwe	Government of Zimbabwe; United National Environment Programme (UNEP); UNDP; GEF	Research	• Assessed vulnerability of smallholder farmers in Chiredzi District and developed adaptation strategies. • Addressed vulnerability drivers; climate risk management through enhancing use of early warning systems and developing community drought preparedness plans.	Brown et al. 2012; www.undp.org/gef/adaptation/docs/CwD2/CwD_M SP_Zim_PAC2.ppt
Zimbabwe	Practical Action	Research/ Policy	• Mainstreaming livelihoods approaches to disaster risk reduction so as to ensure policymakers at district, provincial and national level adopt a livelihoods-centred approach to disaster risk reduction.	Brown et al. 2012
South Africa	Rawsonville Cooperative; Oxfam partner organisation	Research	• Helped seasonal and unemployed workers increase their income through growing gourmet mushrooms and planting crops that survive in cold weather.	Vincent et al. 2011
Malawi	Alliance for a Green Revolution in Africa (AGRA)	Research/ Policy	• Supporting agriculture development across the chain, from funding projects on seeds and soils to markets and policies.	www.agra-alliance.org
Malawi, South Africa, Zimbabwe	African Agricultural Technology Foundation (AATF); ASARECA	Research	• Crop development and technology transfer for African farming systems through crop breeding.	www.aatf-africa.org; www.asareca.org

Malawi, South Africa, Zimbabwe	Action Aid International; ACT; Africare; African Technology Policy System (ATPS); Bureau for Food and Agricultural Policy (BFAP); CGIAR; FAO; Forum for Agricultural Research in Africa (FARA); World Agroforestry Centre (ICRAF)	Research/ Policy	• Integration of disaster reduction into schools. • Integration of vulnerability and adaptation to climate change into sustainable development policy planning and implementation. • Training programmes on climate change adaptation for policymakers. • Natural resources management including water harvesting techniques. • Modelling of climate change effects on crops, especially maize, and access to technology. • Information dissemination through radio plays. • Conservation agriculture.	Mumba and Harding 2009; www.africare.org www.bfap.co.za www.cgiar.org www.fara-africa.org
Zimbabwe	National Agricultural Extension Services (AREX)	Research	• Facilitates smallholder farmers to adapt and cope better with climate variability and change through use of NGOs' global experiences on climate change adaptation and research in agriculture and meteorological services in developing countries.	Mapfumo et al. 2013; www.practicalaction.org
Mostly Africa	Environnement et Développement du Tiers-Monde (ENDA)	Policy	• Lobbying, policy dialogue and multilateral agreements on climate change. • Community level climate change adaptation programmes. Multi-scalar activities.	www.enda.sn
Malawi, South Africa, Zimbabwe	National universities including the University of Zimbabwe, University of Free State and Bunda College of the University of Malawi	Research	• Researchers and students conduct work on climate change adaptation and co-learn with smallholder farmers to be innovative and use 'best-fit' techniques in their fields. • Education and training workshops: a programme of policy research and teaching fellowships with related curriculum. • Development and strategic matching of African and international institutions, where outside knowledge and resources can enhance given areas of expertise. • Researchers are working with planners and farmers to develop modelling scenarios that will improve access to climate information and offer a range of options to help them prepare for a water-scarce future. • Climate change adaptation for improved livelihoods in Malawi.	Denton et al. 2010; Synnevag and Lambrou 2012.
Malawi	Ministry of Agriculture and Food Security	Research	• Dissemination of climate smart agricultural technologies such as reduced tillage, agro-forestry trees, legumes and improved maize varieties through the Research and Extension System.	Synnevag and Lambrou 2012

South Africa	IDRC in collaboration with researchers from the University of Cape Town, University of Kwa-Zulu Natal and University of Free State	Policy	• Development of a model which will allow policymakers to make informed adaptation decisions based on a combination of regional climate change models that can measure impact on water levels, farming systems and urban water use. • Enable capacity building among water managers, academic community and general public with regard to climate change variability, vulnerability and possible adaptation strategies.	www.idrc.ca/ccaa
South Africa, Malawi, Zimbabwe	FANRPAN	Research/ Policy	• Food security and the impacts of CC. Also some work on vulnerability. • Research into adaptation strategies and building research capacity.	www.fanrpan.org
Malawi	Red Cross	Research	• Disaster relief and climate change adaptation.	www.redcross.org
South Africa	SouthSouthNorth	Research	• Community based capacity building, e.g. drought resistant Rooibos tea varieties.	www.southsouthnorth.org
Africa	World Wide Fund for Nature (WWF)	Research	• Nature conservation, natural resource management.	www.worldwildlife.org
Zimbabwe	Zimbabwe Regional Environment Organization (ZERO)	Research/ Policy	• Capacity building through installation of wind power for home use and irrigation pumps, helping rural villages to cope with water shortage. • Scaling up local adaptation needs to national and international policy.	www.zeroregional.com

5.4 State of knowledge on funding streams for policies and strategies on adaptation in the agricultural sector at national and regional levels

Engagement with various stakeholders at the implementation level suggests that climate change adaptation funding streams are either not commonly known or the mechanisms for accessing the funding are beyond the capacity of institutions and practitioners in the region. Major funding sources for the commonly known research and development initiatives related to climate change adaptation include the following:

- GEF supporting the development of NAPAs
- United Nations Convention to Combat Desertification programmes (e.g. Desert Margins Program)
- IDRC (including funding of the CCAA)
- DFID (also funding the CCAA) (e.g. Brown et al. 2012)
- UNDP
- CGIAR funding mechanisms such as for the Climate Change Challenge Program
- Bill and Melinda Gates Foundation through the activities of the Alliance for a Green Revolution in Africa (AGRA)
- African Development Bank (AfDB) through the COMESA initiative
- United States Agency for International Development (USAID)
- The World Bank (e.g. activities of the Global Facility for Disaster Reduction and Recovery in Malawi)

However, future funding mechanisms for development and/or analysis of climate change adaptation processes largely remain unclear.

5.5 Key barriers to uptake of research evidence for policy formulation

There is generally no documentation of evidence-based policymaking processes and their impacts in most of the countries in Southern Africa. Addressing these deficiencies is particularly important in the development of climate change adaptation policies, which have ramifications across different development sectors. Notable barriers to uptake of research evidence in Southern Africa include the following:

- Disconnect between UNFCCC processes and local-level evidence of the nature and causes of vulnerability of livelihood systems as well as mechanisms for adaptation.
- Lack of strategic incentives and appropriate institutional and policy mechanisms for involving different levels of policymakers in development research processes.
- Most of the literature revealed lack of dialogue between research and development practitioners and policymakers as a major barrier. Interventions that broke this barrier, such as CCAA projects and the Government of Zimbabwe/UNDP/GEF Coping with Drought and Climate Change project, recorded positive outcomes.
- Limited research capacity to generate the necessary evidence: Most of the research studies are (for various reasons) isolated in time and space, requiring significant effort by researchers to consolidate (e.g. meta-analysis of existing data from different but related studies) and/or synthesise and discern key policy messages.
- Limited capacity of policymaking bodies to assimilate empirical research outputs. Those studies that involve participatory action and co-learning processes provide evidence that the capacity of policymakers at different levels can be enhanced, including their capacity to demand research results as opposed to the current dominance of supply-driven policy briefs and research findings sent to policymakers.

6 Gaps in climate change adaptation research and policy in the agricultural sector

The review revealed several research and policy gaps that if addressed could enhance climate change adaptation processes at different levels in Southern Africa. Overall, the critical lack of empirical research and development studies/interventions covering diverse contexts already account for many of the glaring knowledge gaps.

- *Building empirical evidence of climate change impacts and application of adaptation options:* The current body of knowledge within the region is too thin to inform the formulation of comprehensive climate change policy frameworks and implementation plans. The intricate nature of economic, governance/political, technical and socio-cultural factors determining vulnerability and adaptive capacities of households, communities and institutions make climate change adaptation one of the most complex subjects of development research in the region. Implications on capacity building in terms of methodologies, approaches, technical expertise and research infrastructure are therefore bigger than can currently be served by tradition.
- *Harmonisation of concepts, methods and tools for vulnerability assessment:* A number of vulnerability assessment studies have been conducted, but it remains unclear if different methods are necessary for understanding climate change. The concept of vulnerability in the context of climate change is clearly defined in IPCC reports but conclusions have been made in some climate change literature based on somewhat different concepts. This has implications for how policymaking processes are subsequently influenced.
- *Identifying critical variables for improving quality of seasonal forecasts and early warning systems:* Most of the national policy and strategy documents emphasise the

importance of seasonal weather forecasting and early warning systems, but there is no clarity on critical variables to be monitored, and the requirements for matching instrumentation and associated expertise at the national and regional levels to improve the quality of data on forecasts.

- *Lack of data and empirical studies to inform budgetary processes for adaptation:* There was limited evidence on quantification of the costs of adaptation processes for specific communities. Operationalisation of adaptation action plans is therefore in itself a major challenge, and is likely by be constrained by poor justification of both actions and budgets.

- *Understanding micro-level impacts of climate change and variability in agricultural systems:* Climate change and variability impacts in agriculture have tended to be reasoned on the basis of traditionally known factors regulating biophysical (physical, chemical and biological) and socio-ecological (interactions) processes. However, one of the impacts of climate change may be an alteration of these regular processes (e.g. soil processes, biodiversity, hydrological cycles, human systems behaviour). Specialist process research is therefore necessary to understand micro-level impacts of climate change and variability in agricultural production systems. Examples in agriculture include revisiting the current understanding of:

    - Dimensions of crop-soil-water interaction patterns to enhance efficiency of resource use and targeting. For example, increasing efficiencies in use of available nutrient and water resources in crop and livestock production systems is likely to be a major determinant of adaptation options in Southern Africa where production is constrained by a combination of poor fertility soils and water scarcity.

    - Emerging patterns and causes of post-harvest losses in crop production systems.

    - Patterns in response of local and introduced livestock types and breeds at different scales.

    - Disease surveillance in livestock systems.

    - Emerging patterns in agro-biodiversity such as climate change and variability impacts on pollinators, soil processes, crop-pest and crop-disease interactions.

    - Options for designing efficient management systems for forestry and fisheries to reduce over-exploitation and post-harvest losses.

- *Role of traditional institutions in fostering and maintaining resilience:* Families and communities in Southern Africa have also survived in marginal environments because of strong institutions supporting extended family lifestyles and vibrant rural-urban inter-connections. Development policies in the region have been exceptionally silent in recognising the contribution of these institutional arrangements on resilience of livelihood systems at local, national and regional (trans-border) scales. The dynamics of these social collaborations (and conflicts) in response to climate change and variability effects (direct or indirect) have not received due attention, yet they underpin cross-generational survival strategies for the majority of people in the region. This is despite clear evidence that effective climate change adaptation options are likely to be those rooted in indigenous knowledge systems and building on local practices. Comprehensive research on these issues is likely to generate key development insights that can inform cross cutting policies, especially those related to gender and HIV/AIDs. Currently there is a strong show of will on gender mainstreaming in agriculture and natural resources management, but content on the mechanisms is critically lacking.

- *Critical analysis of resource use efficiencies and trade-offs for current and alternative adaptation options:* Institutional mechanisms regulating interactions among cropping, livestock and natural resources (including wildlife, forestry and fisheries) management schemes within rural communities and between rural and urban/peri-urban communities need to be evaluated. The foregoing review indicated that climate change can influence resource access and sharing arrangements, socio-political conflicts related to resource governance, as well as the relative impacts of technological interventions/access. Further understanding is required on how climate change and variability may enhance or upset some of the key traditional sources of resilience for diverse farming communities.

- *Understanding emerging gender dynamics in the context of climate change adaptation:* Evidence is only beginning to emerge which suggests changing gender roles in response to impacts of climate change and variability, and interventions that yield a critical analysis on the direction and magnitude of such changes as well as effects on livelihood systems is required. This may help to inform the discourse on gender and climate change in agriculture. Current policies indicate increasing awareness of gender issues among stakeholders, but there is no clear evidence of content. Studies are lacking on how the evolution of what are depicted as local cultures and social values today within the predominantly vulnerable communities have been shaped by environmental marginality and past socio-political systems. Such studies could provide key insights on the current value systems as an outcome of past adaptation processes, or lack thereof.

- *Development of options for commercialisation of smallholder agriculture:* There is need for expanded research programmes on options for sustainable agricultural intensification, and on understanding circumstances where extensification may hold promise now and in the future. Outcome of analyses of trade-offs between extensification and intensification options are likely to be critical in informing future policy directions. Currently, there is also a glaring knowledge gap and no data on climate change and variability effects on production and trade of industrial export crops that include cotton, rice, coffee, cashew and macadamia nuts, tobacco, groundnut, tea, sugarcane and horticultural crops (especially flowers).

- *Development of 'climate smart agriculture' systems:* This is an area that has gained momentum in research over the past few years, but the conceptualisation and application of the underlying principles has generally been informed by speculative arguments with no supporting empirical evidence. This is likely to misdirect policymaking processes on potentials and limitations of emerging agricultural technologies and their suitability to diverse local contexts. For example, a wide range of ISFM and CA technologies have been developed and tested under different agro-ecologies in the region, but their potential role in climate change adaptation have largely not been studied in sufficient detail to inform policy.

- *South African agriculture in transition:* Improvement of agriculture's contribution to national GDP is not a major objective of South African agricultural policy at present, and this has implications on the dynamics of vulnerabilities and therefore on relative adaptive capacity of the country's rural communities to climate change. Currently 95 percent of the country's marketable crops are produced in the large-scale commercial sector. Perceptions about the declining importance of farming in South Africa may possibly send an 'out of fashion' message to the country's youth, with strong implications for the future of national and regional food security as well as the economics of industrial development.

- *Enhancing crop-livestock interactions:* Available evidence from literature suggests that research in the region has focused more on crops, most likely because of the region's critical problems of food insecurity. This has largely been at the expense of other subsectors including livestock, forestry (natural resources) and fisheries. However, with increasing challenges of climate change, livestock production has generally been projected to offer a more favourable adaptation strategy than cropping. Nonetheless, the region also faces critical problems of feed shortages, particularly during the long and expanding dry seasons. Any future policies aimed at increasing productivity and competitiveness of the agricultural production systems will therefore have to consider the management of crop-livestock interactions as a critical component.

- *Analysing trade-offs between irrigated and rain-fed systems:* While irrigation development is emerging as a major area of focus for national policies and strategies, the potential negative impacts of declining rainfall patterns on agricultural water have tended to be ignored in policy formulation. There are no clear indications that due consideration is being given to options for increasing productivity in rain-fed cropping systems. With no empirical evidence to back up some of the policies supporting big investments in irrigation infrastructure development, costly miscalculations could be made.

- *Critical analysis of implications of past research and development intervention programmes on current and possibly future manifestations of vulnerabilities:* Current discourse seems to imply that existing livelihood systems inherently lack resilience regardless of the differences in community exposures to multiple stress factors other than climate change and variability. However, there is little empirical evidence demonstrating how, and to what extent, past intervention programmes have really reduced vulnerabilities of the poor and disadvantaged rural communities. The changing context of development interventions due to climate change may also require governments to revisit some of the past development policies that may be now rendered relevant. Climate change also brings to the fore possible weaknesses in current approaches and methodologies for measuring vulnerability and impact in development (e.g. against the changing context of development interventions and multiple stress factors).

- *Generation of context-specific adaptation options:* There is limited empirical data upon which generalisations of potential impacts of climate change in a country can be made to inform local adaptation processes, yet adaptation is well known to be a local phenomenon. This strongly suggests a need to generate site-specific data and empirical evidence that can inform technical interventions and policy processes at the local level. This also brings to the fore the importance of engaging local-level decision-makers as probably more important agents of change than national and regional stakeholders.

7 Key stakeholders on climate change adaptation in agriculture and opportunities for collaboration

Although agriculture is often at the top of a list of those development sectors considered most vulnerable to climate change and variability, national ministries of environment have generally been the custodians of climate change policy processes. This will likely limit the scope for adaptation in the sector in cases where coordination between such separate ministries fails. Nonetheless, there is strong evidence of participation of diverse stakeholder in all the countries studied, which include government departments, national research institutions and universities, farmer organisations, NGOs and civil society organisations among other (Table 2). The organisations have generally been brought together at national platforms facilitated by respective departments in the ministries of environment (e.g. Climate Change Committee in the Department of Environmental Affairs in Malawi). However, the intensity of interaction among these institutions and organisations have been generally limited to specific project contexts as current policies do not essentially provide for funding of the platforms. A major missing link has been rural institutions and local level structures of farmer organisations, which are supposed to provide a 'grassroots' perspective to the discussions on climate change adaptation.

8 Conclusions and recommendations

Emerging trends on climate change and variability present a major threat to the predominantly rain-fed agriculture sector in Southern Africa, rendering the livelihoods of the majority of both rural and urban communities vulnerable. The agriculture sector in the region, which embraces major forms of natural resources including forestry and fisheries systems, is a major pillar of economic development, providing for food security, employment, industrial raw materials and foreign exchange earnings. The sector accounts for up to 30 percent of national GDP for the regional countries. However, growth of the sector has remained characteristically low (around three percent) and variable, falling way below the expected rate of six percent that is considered sufficient to make the region self-sufficient in food, feed and industrial raw materials. The region

Table 2: Stakeholders involved in research and/or policy on climate change in Southern Africa

a) MALAWI

Description	Stakeholders
State organisations	• Ministry of Agriculture and Food Security • Ministry of Development Planning and Cooperation - Environmental Affairs Department[1] • Ministry of Finance, Economic Planning and Development - Department of Planning[1] - Department of Disaster Management Affairs (DoDMA)[1] • Ministry of Natural Resources, Energy and Environment[1] - Department of Forestry - National Herbarium & Botanic Gardens[1 2] - Department of Climate Change and Meteorological Services[1] • Ministry of Local Government • Ministry of Lands, Physical Planning and Surveys[2] • Ministry of Irrigation and Water Development[2] - Department of Irrigation[1] - Department of Water Resources • Ministry of Agriculture & Food Security - Department of Land Resources Conservation - Department of fisheries • Ministry of Tourism, Wildlife and Culture - Department of National Parks and Wildlife

NGOs	• Christian Aid (*Enhancing Community Resilience Programme*)[1] • Centre for Environmental Policy and Advocacy (CEPA)[1] • UNDP[1] • Concern Universal and ACT Group[2;12] • World Vision International[2] • Miombo Network[2] • Famine Early Warning System Network (FEWS NET)[8] • Action Aid[12] • Wildlife Environmental Society in Malawi (WESM)[12] • Malawi Environment Endowment Trust (MEET)[12]
International organisations	• Total Land Care[1]
Academic/research institutions	• Bunda College of Agriculture[1] - Center for Agricultural Research and Development (CARD)[12] • Mzuzu University (*Reduce Greenhouse Gas Emissions – Biogas Project*)[2] • Leadership in Environment and Development, LEAD chancellor College
Farmer organisations	National Association of Smallholder Farmers[1]
Civil society organisations	• Action Aid[12] • Care Malawi[12] • Evangelical Association of Malawi[12] • Coordination Unit for the Rehabilitation of the Environment (CURE)[12] • Centre for Environmental Policy and Advocacy (CEPA)[12]
Private companies	• ESCOM[12] • Wood Industries Corporation Limited (WICO)[12] • Water Boards[12]
b) SOUTH AFRICA	
State organisations	• Department of Environmental Affairs and Tourism (DEAT),[3] now the Department of Water and Environmental Affairs (DWEA)[4] • South African Weather Services (SAWS)[3] • Agricultural Research Council of South Africa (ARC)[3; 4] • National Climate Change Committee (NCCC), chaired by DWEA with the following members:[4] - Department of Minerals and Energy - Department of Science and Technology - Council for Scientific and Industrial Research[11] - Department of Foreign Affairs[4, 5] - Department of Trade and Industry - Department of Water Affairs and Forestry - Department of Housing - Department of Transport • Department of Agriculture[5] • Department of Health[5] • Department of Lands[5]
NGOs and civil society organisations	• Earth Life Africa (ELA)[4] • Wildlife and Environment Society of South Africa[4] • Environmental Management Group[4] • Resource Africa[4] • South African Climate Action Network (SACAN)[4] • WWF[4] • Norwegian Church Aid[4] • Oxfam (*Anticipating and Reacting to Climate Change in Southern Africa Project*)[4] • International Union for the Conservation of Nature (IUCN)[4] • International Council for Local Environmental Initiatives (ICLEI)[9]
Academic/research institutions	• University of Cape Town Climate Systems Analysis Group (CSAG)[4] • University of the Witwatersrand School of Geography, Archaeology and Environmental Studies[4] • University of KwaZulu-Natal Institute of Natural Resources[4] • University of Free State[4; 10] - Department of Agricultural Economics (*Managing Climate Risks for Agriculture and Water Resources in South Africa*)
Private companies	• Monsanto[13] • Syngenta[13] • Bayer[13]

c) ZIMBABWE

State organisations	• Ministry of Environment and Natural Resources Management
	  - Environmental Management Agency (EMA) (*Coping with Drought Project, 2008-2012*)[6; 7]
	• National Climate Change Office
	• Department of Meteorological Services
	• Ministry of Energy
	• Ministry of Agriculture
	  - Department of Research and Specialist Services (DR&SS)
	  - Department of Agricultural, Technical and Extension Services (AGRITEX)
	  - Department of Irrigation
	• National Economic Planning Commission
	• National Early Warning Unit (NEWU)
	• Agricultural Research Council of Zimbabwe (ARC)

NGOs and civil society organisations	• Zimbabwe Environmental Law Association (ZELA)[7] • Practical Action[7] • ZERO[7] • Oxfam GB • Environment Africa • WWF • IIED • Africa 2000 • Communal Areas Management Programme for Indigenous Resources (CAMPFIRE) • Business Council for Sustainable Development in Zimbabwe (BCSDZ)[7]
International organisations	• United Nations Educational, Scientific and Cultural Organization (UNESCO)[7] • FAO[7] • UNDP (*Coping with Drought Project*)[7] • African Centre for Technology Studies (ACTS) (*Community Based Adaptation to Climate Change*) • British Council in Zimbabwe[7] • CGIAR Centres

Academic/research institutions	• University of Zimbabwe[7]
	  - Department of Soil Science and Agricultural Engineering7
	    - SOFECSA (*Lack of Resilience in African Smallholder Farming, CCAA Project 2007-2010*)[7]
	  - Department of Geography and Environmental Science[7]
	  - Institute of Environmental Studies (IES)[7]
	  - Department of Civil Engineering[7]
	• Midlands State University (*Building Capacity to Adapt to Climate Change in Zambia and Zimbabwe, CCAA Project 2007-2010*)[7]

Private companies	• Seed Co • Windmill Fertilizers

Sources: [1]CEPA (2012); [2]Government of Malawi (2006); [3]Government of South Africa (2004); [4]Madzwamuse (2010); [5]DEAT,2004; [6]www.ema.xo.zw; [7]Chagutah (2010); [8]Kirrane et al. (2012); [9]www.iclei.org; [10]www.natagri.ufs.ac.za; [11]www.csir.co.za; [12]Jumbe et al. (2008); [13]Agrawala et al. (2011)

therefore presents an extraordinary development paradox: agriculture is considered the backbone of the national economies and supports the livelihood of 60-90 percent of the population (with the notable exception of South Africa); yet the countries are faced with low production and chronic food insecurity, with evidence of failure by governments to invest significantly in the sector.

Across the region, national economies suffer from chronic policy failures to address the multiple and multi-dimensional stress factors haunting the majority of farmers, particularly among the predominant smallholder communities. Major constraining factors include: diminishing fertility of soils and a declining natural resource base; land degradation; lack of access to land and water; lack of timely access to adequate levels of agricultural inputs; lack of access to insurance and lines of credit; poor rural infrastructure; lack of access to input and output markets; as well as the high socio-economic costs of HIV/AIDS. Based on the available research evidence, it is therefore clear that the pending impacts of climate change and variability will compound these multiple stress factors, creating an extra load of challenges that will not only heighten but change the nature of vulnerabilities for communities within and across the region's rural-urban divide. Evidence suggest that as communities struggle to adapt, the nature and direction of collaborations – and in some cases conflicts – related to access, use and management of resources in cropping, livestock and natural systems (including land, water, wildlife, forestry and fisheries) will continue to change significantly. Matching policy frameworks are therefore required to promote positive outcomes out of these emerging change processes.

The review shows that the sources of vulnerability to climate change and variability, particularly for the rural farming communities, are multi-dimensional, and matching adaptation options will require use of integrated approaches to research and development. There are strong indications that conditions of perennial food insecurity, declining land productivity and a shrinking natural resource base, combined with the legacies of the historical drivers of poverty (e.g. exclusion from mainstream economic activities and lack of access to land, water and insurance) will continue to make the population of Southern Africa highly vulnerable to emerging impacts of climate change. Climate change adaptation therefore emerges as a critical development issue for the region. Analysis of past climatic trends, although often based on limited data, has produced findings that are consistent with major IPCC projections for the region, providing key starting points for understanding climate change processes. There is evidence of increasing ambient air temperature, increased frequency of droughts and in particular the worsening of rainfall season quality due to poor distribution as well as early and end of season droughts. Effectively, potential growing areas for the major staple cereals (particularly maize) will be significantly reduced, while water resources for crop and livestock production systems and fisheries will also be reduced. There are already emerging trends of increased dependency on common natural resource pools such as forest, rangelands and fisheries by poorer sections of communities, including women and youth, as crop production continues to fail. This is also against evidence of a major decline in these same resources, which in turn is attributed to over-harvesting by a growing population and sensitivities of the natural systems to changing climatic conditions. It is therefore concluded that the required levels of climate change adaptation into the future is beyond the provisions of the available common natural resource pools without significant external (management) interventions. For example, fisheries in countries such as Malawi and Zimbabwe are inherently in crisis due to high levels of poverty and food insecurity, as fish is often the only readily available food source, resulting in over-exploitation of already diminishing fish stocks. Addressing food security problems through stabilisation of agricultural productivity, development of mechanisms for increasing land productivity and devising options for reducing degradation should therefore be considered a priority area in the region's climate change adaptation policies.

Over-reliance on maize significantly restricts livelihood options for the majority of Southern Africa's population, and is likely to deepen the food insecurity crises into the future given the projected decline in rainfall and worsening seasonal quality. However, only when options for ensuring consistent availability of sufficient quantities of maize grain in local and regional markets (i.e. the region's self-sufficiency in maize) can the communities be delivered out of this 'maize poverty trap'. Lack of appropriate policies to ensure sustainable intensification of the region's maize-based cropping systems therefore undermines the potential for diversification into other high value agricultural enterprises, as extensification strategies are more often used by farmers to increase production. There is also evidence of increasing share value of livestock in the total revenue of the agricultural sector as farmers find cropping riskier with deteriorating quality of cropping seasons. Any future climate adaptation policies focusing agricultural interventions in the region will therefore need to address sustainable options for managing crop-livestock interactions. However, availability of feed resources remains a major threat to livestock production due to declining productivity of both crop and pasture lands.

Analysis of available empirical evidence from research on climate change adaptation on one hand, and key national strategies and policies on agriculture and climate change in the region on the other, reveals a major disconnect between research findings and current policymaking processes. The body of empirical evidence (however limited) emerging from research is often not reflected in current national policy documents. For example, available literature clearly indicates a convergence of opinion on the major causes of vulnerability and the need to transform Southern Africa's agricultural sector in order to foster resilience of farming systems in the face of climate change. However, there is less clarity in the current policy frameworks on how such transformative change processes can be brought about. This is despite existing evidence of achievements in the development and testing of adaptation options with 'grassroots' communities by diverse research organisations. One can therefore conclude that the major constraint to policymaking on climate change in Southern Africa is not necessarily lack of empirical evidence, but may also be failure by policymakers to use available empirical evidence. These findings further suggest that current failures in linking research to policy could be a major barrier to further research and development innovations for climate change adaptation.

Major knowledge gaps widely exist across disciplines on how local-level changes in climatic factors (e.g. rainfall, temperature, humidity and air circulation patterns) across spatial and temporal scales influence the socio-ecological processes that underpin agricultural production systems. Current research on climate change in the region has tended to focus (justifiably) on assessing trends in major climate variables, farmers' current coping strategies, knowledge systems and sources of vulnerability, as well as identifying opportunities for adaptation. However, intervention studies with communities have been critically low, rendering research-to-policy linkages extremely weak or seemingly unnecessary in some cases. Detailed studies on the effects of changing climate variables on key ecological processes governing crop, livestock and fisheries, including soil-plant-water interactions, plant-insect interactions (e.g. pollinators, pests and disease vectors) and transmission patterns of livestock diseases are critically needed. Such studies will inform emerging change management processes by diverse stakeholders towards adaptation.

Current national climate change policy frameworks are generally works in progress, as they often fail to draw from available empirical evidence. The countries still require supporting empirical evidence and technical inputs based on field experiences in order to inform the development of locally (at community levels) relevant climate change adaptation plans. Notable research to policy dialogue processes have largely been derived from interventions characterised by participatory action research, co-learning and innovation system approaches involving communities, farmer organisations, policymakers and public and private research and extension among other stakeholders. Agricultural policy instruments supporting institutionalisation of these approaches will most likely broaden opportunities for development of context-specific climate change adaptation options in the region.

The following recommendations are made for the national governments and regional policymakers and their relevant development partners:

i) *Develop national and regional policy frameworks to support transformative change processes that take agriculture beyond current models of smallholder farming systems towards more productive, market oriented and resilient systems:* Implementation strategies driving such policies should embrace participatory action, co-learning and co-innovation approaches and processes that enable communities to self-mobilise, self-organise and intensity their market participation at different scales (e.g. local, national, regional). Success will also most likely depend on how policies are made to open new opportunities for commercialisation of smallholder agriculture.

ii) *Enhancing national and regional capacities for climate change research and development to address critical requirements for data and empirical evidence on sustainable land and natural resources management options:* Strategies and comprehensive research and development action plans are required at national and sub-national levels (i.e. districts) to support development of technical and institutional mechanisms for addressing land degradation and declining soil fertility challenges undermining agricultural production. Major interventions are necessary for applied and strategic process research as well as broad-scale development research supporting adaptive testing of appropriate mixes of indigenous and conventional technologies that enhance resource use efficiencies and management of component interactions in crop-livestock systems (e.g. ISFM and CA options). Most current research on these technologies has not been designed in the context of climate change adaptation. Currently, there are no clear policies specifically focused on supporting farmers and service providers to develop or adopt new and improved technologies.

iii) *Establishing institutional mechanisms and technical capacities for bridging current gaps between regional policy formulation and action planning and implementation at the national and sub-national levels:* The development of regional policies should be matched with establishment and/or strengthening of research and development networks/consortia at the national and regional levels.

iv) *Developing comprehensive national policy frameworks for promoting agricultural technology development and innovation systems:* These should be informed by current and future projections on the relative importance of different crop and livestock types and cultivars/breeds as changes occur nationally, regionally and globally in food supply patterns and food taste preferences, against changes in costs of production of certain crops and livestock products. This is likely to inform policy content and targeting in relation to the magnitude and direction of change processes that are required for climate change adaptation in the agriculture sector.

v) *Harmonisation of climate change policies, strategies, programmes and interventions at national and sub-national (provinces or districts) scales:* This is particularly relevant for the agricultural, environmental (including water) and health sectors.

National ministries of environment currently coordinate climate change policies, a result of UNFCCC processes, but many of the climate change adaptation processes will apparently hinge on activities in the agriculture sector.

vi) *Developing targeted (area/context specific) approaches for decentralising and strengthening decision-making:* This should be coupled to the development of policy frameworks for climate change information dissemination and integrated knowledge management in agricultural systems, including strengthening of early warning systems across temporal and spatial scales. One of the key objectives should be to increase capacity and efficiencies in the generation and dissemination of seasonal weather forecast and early warning information, and their interpretation by farmers and extension.

vii) *Enhancing financing and resource mobilisation for supporting the agriculture sector (e.g. establishing national policies consistent with the Maputo Declaration):* National governments should commit funds towards infrastructure (e.g. irrigation) capacity development at different levels, from grassroots communities through extension systems to research, including policy analysis. This will enable sustained generation of empirical evidence at scale in the different agricultural sub-sectors. Development of specialist skills is an obvious pre-requisite for any research process that may be necessary to measure impacts of climate change and understand adaptation needs.

viii) *Development of mechanisms to support establishment/strengthening of interactive platforms at community, sub-national (district and province), nationals and regional scales to promote research to policy engagements and dialogue:* This will not only enhance supply of new information and evidence to policymakers, but also enable policymakers to demand research products and evidence on the missing links. This mode of interaction will most likely increase the relevance of feedback mechanisms established from the grassroots to inform policymaking processes.

End Notes

1 www.merriam-webster.com/dictionary/agriculture

2 http://www.fao.org/docrep/W7314E/w7314e0o.htm

3 http://www.nepad.org/foodsecurity/knowledge/doc/1815/abuja-declaration-fertilizer-african-green-revolution

4 www.sadc.int/about-sadc/overview/sadc-facts-figures

5 www.indexmundi.com/zimbabwe/gdp_composition_by_sector.html

6 www.k4health.org

7 www.undp-alm.org/projects/sccf-cwdcc-zimbabwe

8 www.nepad-caadp.net

References

Abraha, M.G. and Savage, M.J. (2006) 'Potential Impacts of Climate Change on the Grain Yield of Maize for the Midlands of Kwazulu-Natal, South Africa', *Agriculture, Ecosystems and Environment,* 115:150-160

Adger, W.N. (2006) 'Vulnerability', *Global Environmental Change,* 16:268-281

Adjei-Nsiah, S., Kuyper, T.W., Leeuwis, C., Abekoe, M.K., Cobbinah, J., Sakyi-Dawson, O. and Giller, K.E. (2008) 'Farmers' Agronomic and Social Evaluation of Productivity, Yield and N2-Fixation in Different Cowpea Varieties and their Residual N Effects on a Succeeding Maize Crop', *Nutrient Cycling and Agroecosystems,* 80:199-209

Agrawala, S., Carraro, M., Kingsmill, N., Lanzi, E., Mullan, M. and Prudent-Richard, G. (2011). Private Sector Engagement in Adaptation to Climate Change: Approaches to Managing Climate Risks. OECD Environment Working Papers, No. 39, OECD Publishing. http://dx.doi.org/10.1787/5kg221jkf1g7-en

Ajayi, O.C., Akinnifesi, F.K., Sileshi, G. and Chakeredza, S. (2010). Adoption of renewable soil fertility replenishment technologies in the southern African region: Lessons learnt and the way forward. *Natural Resources Forum* 31:306–317

Akinnifesi, F.K., Sileshi, G., Ajayi, O.C., Chirwa, P.W., Mng'omba, S., Chakeredza, S., and Nyoka, B.I. (2008) 'Domestication and Conservation of Indigenous Miombo Fruit Trees for Improving Rural Livelihoods in Southern Africa', *Biodiversity,* 9:72-74

Allison, E.H. and Ellis, F. (2001) 'The Livelihoods Approach and Management of Small-Scale Fisheries', *Marine Policy,* 25:377-388

Allison, E.H. and Mvula, P.M. (2002) *Fishing Livelihoods and Fisheries Management in Malawi.* LADDER Working Paper No 23, Norwich, UK: Overseas Development Group / www.odg.uea.ac.uk/ladder

Allison, E.H., Perry, A.L., Badjeck, M., Adger, W. N., Brown, K., Conway, D., Halls, A.S., Pilling, G.M., Reynolds, J.D., Andrew, N.L. and Dulvy, N.K. (2009). Vulnerability of national economies to the impacts of climate change on fisheries: *Fish and Fisheries* 10(2), 173–196.

Allison, E.H., Adger, N.W., Badjeck, M-C., Brown, K., Conway, D., Dulvy, N.K., Halls, A., Perry, A. and Reynolds, J.D. (2005) *Effects of Climate Change on the Sustainability of Capture and Enhancement Fisheries Important to the Poor: Analysis of the Vulnerability and Adaptability of Fisherfolk Living in Poverty.* DFID Project R4778J, London, UK: Department for International Development / p15166578.pureserver.info/fmsp/r8475.htm

Allison, E.H., Andrews, N.C. and Oliver, J. (2007) 'Enhancing the Resilience of Inland Fisheries and Aquaculture Systems to Climate Change', *SAT eJournal,* 4(1):1-35

Allison, E.H., Ellis, F., Mathieu, L., Musa, A., Mvula, P.M. and Tinch, R. (2000) *Sustainable Livelihood Strategies from Fluctuating Fishery Resources in Malawi and Indonesia*. Final Technical Report, DFID Fisheries Management Science Programme, London, UK: Department for International Development

Allison, E.H., Mvula, P.M. and Ellis, F. (2002) 'Competing Agendas in the Development and Management of Fisheries in Lake Malawi', in Geheb, K. and Sarch, M-T. (eds), *Africa's Inland Fisheries: The Management Challenge,* Kampala, Uganda: Fountain Books, pp.49-88

Andersson, J.A. (2002) Going Places, Staying Home: *Rural-Urban Connections and the Significance of Land in Buhera District, Zimbabwe*. PhD thesis, Wageningen, The Netherlands: Wageningen University

Andersson, J.A. (2001) 'Re-Interpreting the Rural-Urban Connection: Migration Practices and Socio-Cultural Dispositions of Buhera Workers in Harare', *Africa,* 71:82-112

Andersson, J.A., de Garine-Witchatitsky, M., Dzingirai, V., Cumming, D.H.M. and Giller, K.E. (eds) (2012) *Transfrontier Conservation Areas: People Living on the Edge,* London, UK: Routledge

ASSAf (2007) *HIV/AIDS, TB and Nutrition: Scientific Inquiry into the Nutritional Influences on Human Immunity with Special Reference to HIV Infection and Active TB in South Africa,* Pretoria, South Africa: Academy of Science of South Africa

AU/NEPAD (2003) *Comprehensive Africa Agriculture Development Programme (CAADP),* Addis Ababa, Ethiopia and Midrand, South Africa: African Union and New Partnership for Africa's Development

Bänziger, M., Setimela, P.S., Hodson, D. and Vivek, B. (2006) 'Breeding for Improved Abiotic Stress Tolerance in Maize Adapted to Southern Africa', *Agricultural Water Management,* 80:212-224

Bationo, A. (2004) *Managing Nutrient Cycles to Sustain Soil Fertility in Sub-Sahara Africa,* Nairobi, Kenya: Academy Science Publishers for the Tropical Soil Biology and Fertility Programme, International Center for Tropical Agriculture

Benhin, J.K.A. (2006) Climate Change and South African Agriculture: Impacts and Adaptation Options. CEEPA Discussion Paper No. 21, Pretoria, South Africa: Centre for Environmental Economics and Policy in Africa, University of Pretoria

Bilgnaut, J., Ueckermann, L. and Aronson, J. (2009) 'Agriculture Production's Sensitivity to Changes in Climate in South Africa', *South African Journal of Science,* 105:61-63

Brander, K.M. (2007) 'Global Fish Production and Climate Change', *PNAS* 104(50):19704-19714

Brooks, N., Adger, W.N. and Kelly, M. (2005) 'The Determinants of Vulnerability and Adaptive Capacity at the National Level and the Implications for Adaptation', *Global Environmental Change*, 15:151-163

Brown, D., Chanakira, R., Chatiza, K., Dhliwayo, M., Dodman, D., Masiiwa, M., ... and Zvigadza, S. (2012) *Climate Change Impacts, Vulnerability and Adaptation in Zimbabwe*. IIED Climate Change Working Paper No. 3, London, UK: International Institute for Environment and Development

Bryan, E., Deressa, T.T., Gbetibouo, G.A. and Ringler, C. (2009) 'Adaptation to Climate Change in Ethiopia and South Africa: Options and Constraints', *Environmental Science and Policy,* 21:413-426

Büscher, B.E. and Mutimukuru, T. (2007) 'Buzzing Too Far? The Ideological Echo of Global Governance Concepts on the Local Level: The Case of the Mafungautsi Forest in Zimbabwe', *Development Southern Africa,* 24(5):649-664

Campbell, B., Ed. (1996) *The Miombo in Transition: Woodland and Welfare in Southern Africa,* Bogor, Indonesia: Centre for International Forest Research

Campbell, B., Grundy, I., and Matose, F. (1993) 'Tree and Woodland Resources: The Technical Practices of Small-Scale Farmers', in Bradley, P.N. and McNamara, K. (eds), *Living with Trees: Policies for Forestry Management in Zimbabwe*. Technical Paper No. 210, Washington, DC: The World Bank, pp.29-62

Carr, S.J. (2003) 'More People More Soil Degradation: The Malawi Experience', *African Crop Science Journal,* 6:401-405

Casale, M., Drimie, S., Quinlan, T. and Ziervogel, G. (2010) 'Understanding Vulnerability in Southern Africa: Comparative Findings Using a Multiple-Stressor Approach in South Africa and Malawi', *Regional Environmental Change,* 10:157-168

Cavendish, W. (2000) 'Empirical Regularities in the Poverty-Environment Relationship of Rural Households: Evidence from Zimbabwe', *World Development*, 28:1979-2003

CEPA (2012) *Policy Framework for Climate Change Adaptation and Disaster Risk Reduction in Malawi: A Review of Key Policies and Legislation,* Blantyre, Malawi: Centre for Environmental Policy and Advocacy

Chagutah, T. (2010) *Climate Change Vulnerability and Adaptation Preparedness in South Africa,* Cape Town, South Africa: Heinrich Böll Stiftung Southern Africa

Challinor, A., Wheeler, T., Garforth, C., Craufurd, P. and Kassam, A. (2007) 'Assessing the Vulnerability of Food Crop Systems in Africa to Climate Change', *Climatic Change,* 83:381-399

Chifamba, P.C. (2000) 'The Relationship of Temperature and Hydrological Factors to Catch per Unit Effort, Condition and Size of the Freshwater Sardine, *Limnothris samiodon,* (Boulenger), in Lake Kariba', *Fisheries Research,* 45:271-281

Chikoore, H. and Unganai, L. (2001) *Integrating Climate Forecast Information in Agricultural Management: A Perspective from Southern Africa,* paper presented at the Open Meeting of the Global Environmental Change Research Community, 6-8 October, Rio de Janeiro, Brazil

Chikowo, R., Corbeels, M., Mapfumo, P. Tittonell, P,. Vanlauwe, B. and Giller, K. E. 2010. Nitrogen and phosphorus capture and recovery efficiencies, and crop responses to a range of soil fertility management strategies in sub-Saharan Africa. *Nutrient cycling in agro-ecosystems* 88:59-77

Chilonda, P., Machethe, C. and Minde, I. (2007) *Poverty, Food Security and Agricultural Trends in Southern Africa.* ReSAKSS Working Paper 1, International Crops Research Institute for the Semi-Arid Tropics, International Food Policy Research Institute and International Water Management Institute

Chilowa, W. (1998) 'The Impact of Agricultural Liberalization on Food Security in Malawi', *Food Policy,* 23:553-569

Chirwa, E.W. and Matita, M. (2012) *From Subsistence to Smallholder Commercial Farming in Malawi: A Case of NASFAM Commercialisation Initiatives,* FAC Working Paper 037, Brighton, UK: Future Agricultures Consortium

Clarke, J., Cavendish, W. and Coote, C. (1996) 'Rural Households and Miombo Woodlands: Use, Value and Management', in Campbell, B., Ed., *The Miombo in Transition: Woodlands and Welfare in Africa,* Bogor, Indonesia: Centre for International Forestry Research, pp.101-136

Cousins, B. (1997) *Decision-Making in Communal Area Grazing Schemes,* PhD thesis, Harare, Zimbabwe: Centre for Applied Social Sciences, University of Zimbabwe

Crespo, O., Hachigonta, S. and Tadross, M., (2011) 'Sensitivity of Southern African Maize Yields to the Definition of Sowing Dekad in a Changing Climate', *Climate Change,* 106:267-283

Cumhur, A. and Malcolm, S.C. (2008) 'The Effects of Global Climate Change on Agriculture', *American-Eurasian Journal of Agriculture,* 3(5):672-676

Davies, G.M., Pollard, L. and Mwenda, M.D. (2010) 'Perceptions of Land-Degradation, Forest Restoration and Fire Management: A Case Study from Malawi', *Land Degradation and Development,* 21:546-556

DEAT (2004). A National Climate Change Response Strategy for South Africa. Department of Environmental Affairs and Tourism, Republic of South Africa, Pretoria, South Africa. 39 pp.

Delgado, C.L. (2005) 'Rising Demand for Meat and Milk in Developing Countries: Implications for Grasslands-Based Livestock Production', in McGilloway, D.A., Ed., *Grassland: A Global Resource,* Wageningen, The Netherlands: Wageningen Academic Publishers, pp.29-39

Delgado, C.L. (1999) 'Sources of Growth in Smallholder Agriculture in Sub-Saharan Africa: The Role of Vertical Integration of Smallholders with Processors and Marketers of High-Value Items', *Agrekon*, 38:165-189

Delve, R.J., Cadisch, G., Tanner, J.C., Thorpe, P.J. and Giller, K.E. (2001) 'Implications of Livestock Feeding Management on Soil Fertility in Smallholder Farming Systems of Sub-Saharan Africa', *Agriculture, Ecosystems and Environment,* 84: 227-243

Denton, F., O'Neill, M. and Stone, J.M.R. (2010) *Adapting to Climate Change in Africa: The Role of Research and Capacity Development*. Special Report, Washington, DC: World Bank Institute

Dercon, S. (2011) *Is Green Growth Good for the Poor?* Paper prepared for the World Bank Project on Green Growth, Oxford, UK: University of Oxford

Dercon, S. (2009) 'Rural Poverty: Old Challenges in New Contexts', *World Bank Research Observer*, 24:1-28

Dercon, S. (2007) *Fate and Fear: Risk and its Consequences in Africa.* Global Poverty Research Group Working Paper, Oxford, UK: University of Oxford

Desanker, P. and Magadza, C.H.D. (2001) 'Africa', in *Climate Change 2001: Impacts and Adaptations. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change,* Cambridge, UK: Cambridge University Press

Dinar, A., Hassan, R., Mendelsohn, R. and Benhin, J. (2008) *Climate Change and Agriculture in Africa: Impact Assessment and Adaptation Strategies*, London, UK: Earthscan

Dixon, R.K., Smith, J. and Guill, S. (2003) 'Life on the Edge: Vulnerability and Adaptation of African Ecosystems to Global Climate Change', *Mitigation and Adaptation Strategies for Global Change,* 8:93-113

Dixon, J., Gulliver, A. and Gibbon, D. (2001). *Farming Systems and Poverty: Improving farmers' livelihoods in a changing world.* FAO and World Bank, Rome and Washington D.C.

Dorward, A. and Chirwa, E. (2011) 'The Agricultural Input Subsidy Programme 2005/06 to 2008/09', *International Journal of Agricultural Sustainability,* 9:232-247

Downing, T.E. (2003) 'Lessons from Famine Early Warning and Food Security for Understanding Adaptation to Climate Change: Toward a Vulnerability/Adaptation Science?', in Smith, J.B., Klein, R.J.T. and Huq, S. (eds), *Climate Change, Adaptive Capacity and Development,* London, UK: Imperial College Press

Dulal, H.B., Brodnig, G., Onoriose, C.G. and Thakur, H.K. (2010) *Capitalizing on Assets: Vulnerability and Adaptation to Climate Change in Nepal.* Social Development Dorking Paper 121, Washington, DC: The World Bank

Dulvy, N.K., Reynolds, J.D., Pilling, G.M., Pinnegar, J.K., Phillips, J.S., Allison, E.H., and Badjeck, M.C. (2010) 'Fisheries Management and Governance Challenges in a Climate Change', in *The Economics of Adapting Fisheries to Climate Change,* Paris, France: Organisation for Economic Co-operation and Development

Dutta, R. (2009) 'Information Needs and Information-Seeking Behaviour in Developing Countries: A Review of the Research', *The International Information and Library Review,* 41:44-51

Ellis, F., Kutengule, M. and Nyasala, F. (2003) 'Livelihoods and Rural Poverty Reduction in Malawi', *World Development,* 31: 1495-1510

FAO (2011) *Global Forest Resources Assessment 2010.* Forestry Paper #165, Rome, Italy: Food and Agriculture Organization

FAO, 2010. "Climate-Smart" Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. 41 p.

FAO (2008) 'Climate Change Implications for Fisheries and Aquaculture', in *The State of Fisheries and Aquaculture (2008),* Rome, Italy: Food and Agriculture Organization, pp.87-91

FAO (2007) *Building Adaptive Capacity to Climate Change: Policies to Sustain Livelihoods and Fisheries.* New Directions in Fisheries No. 8, Rome, Italy: Food and Agriculture Organization

Fischer, G., Shah, M., Tubiello, F.N. and Van Velhuizen, H. (2005) 'Socio-Economic and Climate Change Impacts on Agriculture: An Integrated Assessment, 1990-2080', *Philosophical Transactions of the Royal Society B,* 360:2067-2083

Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C.S., Walker, B., ... and Svedin, U. (2010) *Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformations,* Stockholm, Sweden: Environmental Advisory Council to the Swedish Government

Freeman, A., Kaitibie, S., Moyo, S. and Perry, B. (2007) *Livestock, Livelihoods and Vulnerability in Lesotho, Malawi and Zambia,* Nairobi, Kenya and Rome, Italy: International Livestock Research Institute and Food and Agriculture Organization

Frost, P., Campbell, B., Luckert, M., Mutamba, M., Madondo, A. and Kozanyi, W. (2007) 'In Search of Improved Livelihoods in Semi-Arid Regions through Local Management of Natural Resources: Lessons from Case Studies in Zimbabwe', *World Development*, 35:1961-1974

Gbetibouo, G.A. (2008) *Understanding Farmers' Perceptions and Adaptations to Climate Change and Variability: The Case of the Limpopo Basin, South Africa.* IFPRI Discussion Paper 00849, Washington, DC: International Food Policy Research Institute

Gbetibouo, G.A and Hassan, R.M. (2005) 'Measuring the Economic Impact of Climate Change on Major South African Field Crops: A Ricardian approach', *Global and Planetary Change,* 47:143-152

Giller, K.E., Leeuwis, C., Andersson, J.A., Andriesse, W., Brouwer, A., Frost, P., ... and Windmeijer, P. (2008) 'Competing Claims on Natural Resources: What Role for Science?', *Ecology and Society,* 13(2):34

Giller, K.E., Rowe, E.C., de Ridder, N. and van Keulen, H. (2006) 'Resource Use Dynamics and Interactions in the Tropics: Scaling Up in Space and Time', *Agricultural Systems*, 88: 8-27

Giller, K.E., Tittonell, P., Rufino, M.C. van Wijk, M.T., Zingore, S. Mapfumo, P., ... and Vanlauwe, B. (2011) 'Communicating Complexity: Integrated Assessment of Trade-Offs Concerning Soil Fertility Management Within African Farming Systems to Support Innovation and Development', *Agricultural Systems*, 104 (2):191-203

Government of Malawi (2012) *National Climate Change Policy,* Lilongwe, Malawi: Environmental Affairs Department, Ministry of Environment and Climate Change Management

Government of Malawi (2011) *Sector Policies Response to Climate Change in Malawi: A Comprehensive Gap Analysis,* Lilongwe, Malawi: National Climate Change Programme, Ministry of Finance and Development Planning

Government of Malawi (2008) *Enhancing Agricultural Input Use Efficiency in Malawi. A Research Report of the National Subsidy Programme Technical Support Workshop in Lilongwe, 15-16 April (2008)*, Lilongwe, Malawi: Department of Planning, Ministry of Agriculture

Government of Malawi (2006) *Malawi's National Adaptation Programme of Action (NAPA) Under the United Nations Framework Convention on Climate Change (UNFCCC)*, Lilongwe, Malawi: Department of Environmental Affairs, Ministry of Mines, Natural Resources and Environment

Government of Malawi (2002) *Initial National Communication Under the United Nations Framework Convention on Climate Change,* Lilongwe, Malawi: Environmental Affairs Department, Ministry of Natural Resources and Environmental Affairs

Government of South Africa (2012) *Integrated Growth and Development Plan: (2012),* Pretoria, South Africa: Department of Agriculture, Forestry and Fisheries

Government of South Africa (2009) *The Comprehensive Rural Development Programme Framework,* Pretoria, South Africa: Department of Rural Development and Land Reform

Government of South Africa (2004) *A National Climate Change Response Strategy for South Africa,* Pretoria, South Africa: Department of Environmental Affairs and Tourism

Government of South Africa (2002) *Integrated Food Security Strategy for South Africa,* Pretoria, South Africa: Department of Agriculture

Government of Zimbabwe (2013) *Poverty and Poverty Datum Line Analysis in Zimbabwe 2011/12,* Harare, Zimbabwe: Zimbabwe National Statistical Agency

Government of Zimbabwe (2012a) *Comprehensive Agriculture Policy Framework (2012–2032),* Harare, Zimbabwe: Ministry of Agriculture, Mechanization and Irrigation Development

Government of Zimbabwe (2012b) *Second Crop and Livestock Assessment Report,* Harare, Zimbabwe: Ministry of Agriculture, Mechanization and Irrigation Development

Government of Zimbabwe/UNDP/GEF (2009) *Coping with Drought and Climate Change Project. Climate Change: Scenarios for the Save Catchment of Zimbabwe with Special Reference to Chiredzi, Synthesis Report,* Harare, Zimbabwe: Environmental Management Agency

Grivetti, L.E. and Ogle, B.M. (2000) 'Value of Traditional Foods in Meeting Macro- and Micronutrient Needs: The Wild Plant Connection', *Nutrition Research Reviews*, 13:31-46

Gukurume, S. (2013) 'Climate Change Variability and Sustainable Agriculture in Zimbabwe's Rural Communities', *Russian Journal of Agricultural and Socio-Economic Sciences,* 2(14):89-100

Gukurume, S., Nhodo, L. and Dube, C. (2010) 'Conservation Farming and the Food Security-Insecurity Matrix in Zimbabwe: A Case Study of Ward 21 Chivi Rural', *Journal of Sustainable Development in Africa,* 12 (7):40-52

Gwandu, T., Mtambanengwe, F., Mapfumo, P., Mashavave, T.C., Chikowo, R. and Nezomba, H. (2013) 'Factors Influencing Access to Integrated Soil Fertility Management Information and Knowledge and its Uptake among Smallholder Farmers in Zimbabwe', *The Journal of Agricultural Education and Extension,* 20(1):79-93

Hachigonta, S., Nelson, G.C., Thomas, T.S. and Sibanda L.M. (2013). *Southern African Agriculture and Climate Change: A Comprehensive Analysis.* International Food Research Institute (IFPRI), Washington DC, USA. 337 pp.

Hara, M., Donda, S. and Njaya, F.J. (2002) 'Lessons from Malawi's Experience with Fisheries Co-Management Initiatives', in Geheb, K. and Sarch, M.T. (eds), *Africa's Inland Fisheries: The Management Challenge,* Kampala, Uganda: Fountain Publishers, pp.31-48

Herrero, M., Thornton, P.K., Gerber, P. and Reid, R. (2009) 'Livestock, Livelihoods and the Environment: Understanding the Trade-Offs', *Current Opinion in Environmental Sustainability,* 1:111-120

Herrero, M., Thornton, P.K., Kruska, R.L. and Reid, R.S. (2008) 'System Dynamics and the Spatial Distribution of Methane Emissions from African Domestic Ruminants to 2030', *Agriculture, Ecosystems and Environment,* 126:122-137

Hudson, J.W. (2002) *Response to Climate Variability in the Livestock Sector in the North West Province, South Africa,* MA thesis, Fort Collins, CA: Colorado State University

Ibrahim, M.G.P. and Alex, R.S. (2008) 'The Impact of Changing Environmental Conditions on Vulnerable Communities in the Shire Valley, Southern Malawi', in *The Future of Drylands*, Springer Netherlands, pp.545-559

IFRC (2001) *World Disasters Report: Focus on Reducing Risks,* Geneva, Switzerland: International Federation of Red Cross and Red Crescent Societies

ILRI (2009) *Climate, Livestock and Poverty: Challenges at the Interface.* Corporate Report 2008–9, Nairobi, Kenya: International Livestock Research Institute

IPCC (2007a) *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* Cambridge, UK: Cambridge University Press

IPCC (2007b) *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* Cambridge, UK: Cambridge University Press

IPCC (2001) *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change,* Cambridge, UK: Cambridge University Press

IUCN (2010) *Building Climate Change Resilience for African Livestock in Sub-Saharan Africa,* Nairobi, Kenya: World Initiative for Sustainable Pastoralism, a program of the International Union for Conservation of Nature, Eastern and Southern Africa Regional Office

Jamu, D.M. and Chimatiro, S. (2004) 'Sustainable Agro-Pisciculture in Malawi', *Entwicklung und Ländlicher Raum,* 38(6):27-28

JIMAT (2008) *Coping with Drought and Climate Change Project: Baseline Study.* Final Report to the Environmental Management Agency and United Nations Development Programme, JIMAT Development Consultants, Harare, Zimbabwe.

Johnson, I.R. and Thornley, J.H.M. (1985) 'Temperature Dependence of Plant and Crop Process', *Annals of Botany,* 55:1-24

Jones, P.J., and Thornton, P.K. (2009). Croppers to livestock keepers: Livelihood transitions to 2050 in Africa due to climate change. *Environmental Science and Policy* 12:427–437.

Jones, P.G., and Thornton, P.K., 2003. The potential impacts of climate change in tropical agriculture: the case of maize in Africa and Latin America in 2055. Global Environmental Change 13, 51-59.

Johnston, P., Hachigonta, S., Sibanda, S.M. and Thomas, T.S. (2012) 'South Africa', in *Southern African Agriculture and Climate Change: A Comprehensive Analysis.* IFPRI Monograph, Washington, DC: International Food Policy Research Institute

Jul-Larsen, E., Kolding, J., Overa, R., Raakjaer Nielsen, J. and van Zweiten, P.A.M. (2003) *Management, Co-Management or No Management?* Major Dilemmas in Southern African Freshwater Fisheries 1: Synthesis Report, FAO Fisheries Technical Paper 426/1, Rome, Italy: Food and Agriculture Organization

Jumbe, C.B.L, Wiyo, K.A, Njewa, E. and Msiska, F.B.M. (2008). The role of government, donors, civil society and the private sector in climate change adaptation in Malawi: Scoping Study Centre for Agricultural Research & Development, Bunda College Lilongwe, Malawi. pp 1-15.

KalengaSaka, J. D. and Msonthi, J.D. (1994) 'Nutritional Value of Edible Fruits of Indigenous Wild Trees in Malawi', *Forest Ecology and Management*, 64:245-248

Kandlinkar, M. and J. Risbey (2000) 'Agricultural Impacts of Climate Change: If Adaptation is the Answer, What is the Question?', *Climatic Change,* 45:529-539

Kanonge, G., Nezomba, H., Chikowo, R., Mtambanengwe, F. and Mapfumo, P. (2009) 'Assessing the Potential Benefits of Organic and Mineral Fertilizer Combinations on Maize and Legume Productivity Under Smallholder Management in Zimbabwe', *African Crop Science Conference Proceedings,* 9:63-70

Kasasa, P., Mpepereki, S., Musiyiwa, K., Makonese, F. and Giller, K.E. (1999) 'Residual Nitrogen Fixation Benefits of Promiscuous Soyabeans to Maize Under Field Conditions', *African Crop Science Journal*, 7:375-382

Kazombo-Phiri, S.F.M. (2005) 'Main Causes of Declining Soil Productivity in Malawi: Effects on Agriculture and Management Technologies Employed to Alleviate the Problems', in Omanya, G.O. and Pasternak, D. (eds), *Sustainable Agriculture for the Drylands.* Proceedings of the International Symposium for Sustainable Dryland Agriculture Systems, 2-5 December 2003, Niamey, Niger, pp.59-66

Kepe, T. (2008) 'Beyond the Numbers: Understanding the Value of Vegetation to Rural Livelihoods in Africa', *Geoforum*, 39:958-968

Kiker, G.A. (2002) *CANEGRO-DSSAT Linkages with Geographic Information Systems: Applications in Climate Change Research for South Africa,* paper presented at the 2nd International CANEGRO Workshop, 9-10 October, South African Sugar Association, Mount Edgecombe, South Africa

Kirrane, C., Sharkey, C. and Naess, L.O. (2012). 'Shaping Strategies: factors and actors in climate change adaptation'. Trócaire & IDS. Dublin, Ireland.

Kruger, A.C. and S. Shongwe (2004) 'Temperature Trends in South Africa: 1960–2003', *International Journal of Climatology*, 24:1929-1945

Kumwenda, J.D.T., Waddington, S.R., Snapp, S.S., Jones, R.B. and Blackie, M.J. (1995) *Soil Fertility Management for Smallholder Maize-Based Cropping Systems of Southern African: A Review.* Network Working Paper No. 1, Harare, Zimbabwe: Soil Fertility Network for Maize-Based Cropping Systems in Countries of Southern Africa, International Maize and Wheat Improvement Center

Lahiff, E., 2007. 'Willing Buyer, Willing Seller': South Africa's failed experiment in market-led agrarian reform. *Third World Quarterly* 28:1577-98.

Leichenko, R.M. and O'Brien, K.L. (2002) 'The Dynamics of Rural Vulnerability to Global Change: The Case of Southern Africa', *Mitigation and Adaptation Strategies for Global Change,* 7:1-18

Lobell, D.B., Bänziger, M., Magorokosho, C. and Vivek, B. (2011) 'Nonlinear Heat Effects on African Maize as Evidenced by Historical Yield Trials', *Nature Climate Change,* 1:42-42

Lobell, D.B., Burke, M.B., Tebaldi, C., Mastrandrea, M.D., Falcon, W.P. and Naylor, R.L. (2008) 'Prioritizing Climate Change Adaptation Needs for Food Security in 2030', *Science*, 319:607-610

Madzwamuse M. 2010. Climate change vulnerability and adaptation preparedness in South Africa. Heinrich Boll Stiftung Southern Africa. pp 1-34.

Mafongoya, P.L., Bationo, A., Kihara, J. and Waswa, B.S. (2006) 'Appropriate Technologies to Replenish Soil Fertility in Southern Africa', *Nutrient Cycling Agroecosystems,* 76:137-151

Magadza, C.H.D. (2011) 'Indications of the Effects of Climate Change on the Pelagic Fishery of Lake Kariba, Zambia–Zimbabwe', *Lake and Reservoirs: Research and Management,* 16:15-22

Magombo, T.M., Kanthiti, G., Phiri, G., Kachulu, M. and Kabuli, H. (2012) *Incidence of Indigenous, Emerging and Innovative Climate Change Adaptation Practices for Smallholder Farmers' Livelihood Security in Chikhwawa District, Southern Malawi.* Working Paper No. 63, Nairobi, Kenya: African Technology Policy Studies Network

Majule, A.E., Stathers, T., Lamboll, R., Liwenga, E.T., Ngongondo, C. and Kalanda-Joshua, M. (2011) *Strengthening Local Agricultural Innovation Systems in Tanzania and Malawi to Adapt to the Challenges and Opportunities Arising from Climate Change and Variability.* Final Technical Report, Nairobi, Kenya: International Development Research Centre, Eastern and Southern Africa Office

Makadho, J.M. (1996) 'Potential Effects of Climate Change on Corn Production in Zimbabwe', *Climate Research*, 6:147-151

Mano, R. and Nhemachena, C. (2007) *Assessment of the Economic Impacts of Climate Change on Agriculture in Zimbabwe: A Ricardian Approach.* CEEPA Discussion Paper 11, Pretoria, South Africa: Centre for Environmental Economics and Policy in Africa, University of Pretoria

Manona, S.S. (2005) *Smallholder Agriculture as Local Economic Development (LED) Strategy in Rural South Africa: Exploring Prospects in Pondoland, Eastern Cape,* MPhil thesis, Cape Town, South Africa: Programme for Land and Agrarian Studies, Faculty of Economic and Management Sciences, University of the Western Cape

Mapedza, E., Wright, J. and Fawcett, R. (2003) 'An Investigation of Land Cover Change in Mafungautsi Forest, Zimbabwe, using GIS and Participatory Mapping', *Applied Geography,* 23:1-21

Mapfumo, P. (2011) 'Comparative Analysis of the Current and Potential Role of Legumes in Integrated Soil Fertility Management in Southern Africa', in Bationo, A., Waswa, B., Okeyo, J.M., Maina, F., Kihara, J. and Mokwunye, U. (eds), *Fighting Poverty in Sub-Saharan Africa: The Multiple Roles of Legumes in Integrated Soil Fertility Management,* 1st Edition, New York, NY: Springer, pp.175-200

Mapfumo, P. (2009) *Integrating Sustainable Soil Fertility Management Innovations in Staple Cereal Systems and Other Value Chains to Enhance Livelihoods and Environmental Systems in Southern Africa*. SOFECSA Technical Annual Report for the Sub-Saharan Challenges Program of the Forum for Agricultural Research in Africa, Harare, Zimbabwe: Soil Fertility Consortium for Southern Africa, International Maize and Wheat Improvement Center

Mapfumo, P. and Giller, K.E. (2001) *Soil Fertility Management Strategies and Practices by Smallholder Farmers in Semi-Arid Areas of Zimbabwe,* Bulawayo, Zimbabwe: International Crops Research Institute for the Semi-Arid Tropics

Mapfumo, P., Adjei-Nsiah, S., Mtambanengwe, F., Chikowo, R. and Giller, K.E. (2013) 'Participatory Action Research (PAR) as an Entry Point for Supporting Climate Change Adaptation by Smallholder Farmers in Africa', *Environmental Development,* 5:6-22

Mapfumo, P., Campbell, B.M., Mpepereki, S. and Mafongoya, P. (2001) 'Legumes in Soil Fertility Management: The Case of Pigeonpea in Smallholder Farming Systems of Zimbabwe', *African Crop Science Journal,* 9:629-644

Mapfumo, P., Chikowo, R. and Mtambanengwe, F. (2010a) *Lack of Resilience in African Smallholder Farming: Exploring Measures to Enhance the Adaptive Capacity of Local Communities to Climate Change.* Final Technical Report to the Climate Change Adaptation in Africa program, Harare, Zimbabwe: University of Zimbabwe

Mapfumo, P., Chikowo, R., Mtambanengwe, F., Adjei-Nsiah, S., Baijukya, F., Maria, R., ... and Giller, K. (2008) 'Farmers' Perceptions Lead to Experimentation and Learning', LEISA, 24:30-31

Mapfumo, P., Mtambanengwe, F. and Chikowo, R. (2010b) *Mobilizing Local Safety Nets for Enhanced Adaptive Capacity to Climate Change and Variability in Zimbabwe.* CCAA Adaptation Insights Brief No. 1, Climate Change Adaptation in Africa

Mapfumo, P., Mtambanengwe, F., Mpepereki, S. and Giller, K.E. 2005. Tapping indigenous herbaceous legumes for soil fertility management by resource-poor farmers in Zimbabwe. *Agriculture Ecosystems & Environment* 109(3-4):221-233.

Maponya, P. and Mpandeli, S. (2012) 'Climate Change and Agricultural Production in South Africa: Impacts and Adaptation Options', *Journal of Agricultural Science,* 4(10):48

Mashavave, T., Mapfumo, P., Mtambanengwe, F., Gwandu, T. and Siziba, S. (2013). Interaction patterns determining improved information and knowledge sharing among smallholder farmers. *African Journal of Agricultural and Resource Economics 8*(1): 1-12

Masike, S. (2007) *The Impacts of Climate Change on Cattle Water Demand and Supply in Khurutshe, Botswana,* PhD thesis, Hamilton, New Zealand: University of Waikato

Matarira, C.H., Makadho, J.C. and Mukahanana-Sangarwe, M. (2004) Vulnerability and Adaptation of Maize Production to Climate Change in Zimbabwe. Government of Zimbabwe Publication, Harare, Zimbabwe.

Matiya, G., Lunduka, R. and Sikwese, M. (2011) *Costing Climate Change Adaptation in Agriculture: A Case Study of Small-Scale Maize Production in Malawi,* London, UK: International Institute for Environment and Development

Mazvimavi, D. (2010) 'Investigating Changes Over Time of Annual Rainfall in Zimbabwe', *Hydrology and Earth System Sciences,* 14:2671-2679

Meadows, M.E and Hoffman, M.T. (2002) 'The Nature, Extent and Causes of Land Degradation in South Africa: Legacy of the Past, Lessons for the Future?', Area, 34:428-437

Midgley, G., Spalding-Fecher, R., Turpie, J. and Winkler, H. (2002) *Economic Impacts of Climate Change in South Africa: A Preliminary Analysis of Unmitigated Damage Costs,* Cape Town, South Africa: Southern Waters Ecological Research and Consulting and the Energy Research Centre, University of Cape Town

Milgroom, J. and Giller, K.E. (2013) 'Courting the Rain: Rethinking Seasonality and Adaptation to Recurrent Drought in Semi-Arid Southern Africa', *Agricultural Systems,* 118:91-104

Miller, F., Osbahr, H., Boyd, E., Thomalla, F., Bharwani, S., Ziervogel, G., ... and Nelson, D. (2010) 'Resilience and Vulnerability: Complementary or Conflicting Concepts?', *Ecology and Society*, 15(3):11

Minson, D.J. (1990) *Forage in Ruminant Nutrition,* San Diego, CA: Academic Press

Moorsom R, Pfouts A. 1993. Drought impacts and preparedness in Namibia. Windhoek, Namibia: NEPRU.

Morgan, J.A., Milchunas, D.G., LeCain, D.R., West, M. and Mosier, A.R. (2007) 'Carbon Dioxide Enrichment Alters Plant Community Structure and Accelerates Shrub Growth in the Shortgrass Steppe', PNAS, 104:14724-14729

Mpepereki, S., Javaheri, F., Davis, P. and Giller KE. (2000) 'Soyabeans and Sustainable Agriculture: Promiscuous Soyabeans in Southern Africa', *Field Crop Research,* 65:137-149

Mtambanengwe, F. and Mapfumo, P. (2009) 'Combating Food Insecurity on Sandy Soils in Zimbabwe: The Legume Challenge', *Symbiosis,* 48:25-36

Mtambanengwe, F. and Mapfumo, P. (2005) 'Organic Matter Management as an Underlying Cause for Soil Fertility Gradients on Smallholder Farms in Zimbabwe', *Nutrient Cycling in Agroecosystems*, 73: 227-243

Mtambanengwe, F., Mapfumo, P., Chikowo, R. and Chamboko, T. (2012) 'Climate Change and Variability: Smallholder Farming Communities in Zimbabwe Portray a Varied Understanding', *African Crop Science Journal*, 20: 227-241

Mudhara, M. (2010) *Agrarian Transformation in Smallholder Agriculture in South Africa: A Diagnosis of Bottlenecks and Public Policy Options,* paper presented at a workshops on Overcoming Inequality and Structural Poverty in South Africa: Towards Inclusive Growth and Development, organized by University of KwaZulu Natal, 20-22 September, Johannesburg, South Africa

Mugabe, F.T., Hachigonta, S., Sibanda, L.M. and Thomas, T.S. (2012) 'Zimbabwe', in *Southern African Agriculture and Climate Change: A Comprehensive Analysis.* IFPRI Monograph, Washington, DC: International Food Policy Research Institute

Muller, J. and Almedom, A.M. (2008) 'What is "Famine Food"? Distinguishing Between Traditional Vegetables and Special Foods for Times of Hunger/Scarcity (Boumba, Niger)', *Human Ecology,* 36:599-607

Mumba, M. and Harding, B. (2009) *A Preliminary Stocktaking: Organisations and Projects Focused on Climate Change Adaptation in Africa.* Stock-Taking Report Contributing to the Africa Adaptation Network as an Integral Part of the Global Adaptation Network Facilitated by the United Nations Environment Programme

Murungweni, C., Andersson, J.A., van Wijk, M.T., Gwitira, I. and Giller, K.E. (2012) 'Zhombwe (*Neorautanenia brachypus* (Harms), C.A.Sm.) – A Recent Discovery for Mitigating Effects of Drought on Livestock in Semi-Arid Areas of Southern Africa', *Ethnobotany Research & Applications,* 10:199-212

Murungweni, C., Van Wijk, M.T., Andersson, J.A., Smaling, E.M.A. and Giller, K.E. (2011) 'Application of Fuzzy Cognitive Mapping in Livelihood Vulnerability Analysis', *Ecology and Society,* 16(4):8

Mutekwa, V.T. (2009) 'Climate Change Impacts and Adaptation in the Agricultural Sector: The Case of Smallholder Farmers in Zimbabwe', *Journal of Sustainable Development in Africa,* 11(2):237-256

Mutimukuru, T., Kozanayi, W. and Nyirenda, R. (2006) 'Catalysing Collaborative Monitoring Processes in Joint Forest Management Situations: The Mafungautsi Forest Case, Zimbabwe', *Journal of Society and Natural Resources,* 9:209-224

Mutsamba, E.F., Nyagumbo, I. and Mafongoya, P.L. (2012) 'Dry Season Crop Residue Management Using Organic Livestock Repellents Under Conservation Agriculture in Zimbabwe', *Journal of Organic Systems,* 7(1):5-13

Ncube, B., Dimes, J.P., Twomlow, S.J., Mupangwa, W. and Giller, K.E. (2007) 'Raising the Productivity of Smallholder Farms Under Semi-Arid Conditions by Use of Small Doses of Manure and Nitrogen: A Case of Participatory Research', *Nutrient Cycling and Agroecosystems,* 77:53-67

Ndebele-Murisa, M.R., Mashonjowa, E. and Trevor, H. (2011) 'The Implications of a Changing Climate on the Kapenta Fish Stocks of Lake Kariba, Zimbabwe', *Transactions of the Royal Society of South Africa*, 66(2):105-119

Nezomba, H., Tauro, T.P., Mtambanengwe, F. and Mapfumo, P. (2010) 'Indigenous Legume Fallows (Indifallows) as an Alternative Soil Fertility Resource in Smallholder Maize Cropping Systems', *Field Crops Research,* 115:149-157

Nhemachena, C. and Hassan, R. (2007) *Micro-Level Analysis of Farmers' Adaptation to Climate Change in Southern Africa*. IFPRI Discussion Paper 00714, Washington, DC: International Food Policy Research Institute

Nicholls, R.J., Wong, P.P., Burkett, V., Codignotto, J., Hay, J., McLean, R., ... and Saito, Y. (2007) 'Coastal Systems and Low-Lying Areas', in *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* Cambridge, UK: Cambridge University Press, pp.315-356

NRC (1981) *Effect of Environment on Nutrient Requirements of Domestic Animals.* Subcommittee on Environmental Stress, National Research Council, Washington, DC: National Academy Press

Nyamangara, J. and Nyagumbo, I. (2010). Interactive effects of selected nutrient resources and tied-ridging on plant growth performance in a semi-arid smallholder farming environment in central Zimbabwe. *Nutrient Cycling in Agroecosystems* 88:103-109

Nyikahadzoi, K., Siziba, S., Mango, N., Mapfumo, P., Adekunhle, A. and Fatunbi, O. (2012) 'Creating Food Self Reliance among the Smallholder Farmers of Eastern Zimbabwe: Exploring the Role of Integrated Agricultural Research for Development', *Food Security,* 4:647-656

Nyong, A., Adesina, F. and Elasha, O.B. (2007) 'The Value of Indigenous Knowledge in Climate Change Mitigation and Adaptation Strategies in the African Sahel', *Mitigation and Adaptation Strategies in Global Change*, 12:787-797

O'Brien, K., T. Quinlan, and G. Ziervogel. 2009. Vulnerability interventions in the context of multiple stressors: lessons from the Southern Africa Vulnerability Initiative (SAVI). *Environmental Science and Policy* 12:23-32.

O'Brien, K.L., Leichenko, R., Kelkar, U., Venema, H., Aandahl, G., Tompkins, H., Javed, A., Bhadwal, S., Barg, S., Nygaard, L. and West, J. (2004) 'Mapping Vulnerability to Multiple Stressors: Climate Change and Globalization in India', *Global Environmental Change,* 14:303-313

Oettle, N., Fakir, S., Wentzel, W., Giddings, S. and Whiteside, M. (1998) *Encouraging Sustainable Smallholder Agriculture in South Africa.* Report for the Department for International Development Project R6452CA, Agricultural Services Reform in Southern Africa. Stroud, UK: Environment and Development Consultancy Ltd.

Orr, A. and Mwale, B. (2001) Adapting to Adjustment: 'Smallholder Livelihood Strategies in Southern Malawi', *World Development*, 29:1325-1343

Patt, A. and Gwata, C. (2002) 'Effective Seasonal Climate Change Forecast Applications: Examining Constraints for Subsistence Farmers in Zimbabwe', *Global Environmental Change,* 12:185-195

Patt, A., Suarez, P. and Gwata, C. (2005) 'Effects of Seasonal Climate Forecasts and Participatory Workshops Among Subsistence Farmers in Zimbabwe', *PNAS* 102(35):12623-12628

Pawluk, R.R., Sandor, J.A. and Tabor, J.A. (1992) 'The Role of Indigenous Soil Knowledge in Agricultural Development', *Journal of Soil and Water Conservation,* 47:298-302

Phillips, J.G., Cane, M.A. and Rosenzweig, C., (1998) ENSO, Seasonal Rainfall Patterns and Simulated Maize Yield Variability in Zimbabwe', *Agricultural and Forest Meteorology,* 90:39-50

Phillips, J.G., Makaudze, E. and Unganai, L. (2001) 'Current and Potential Use of Climate Forecasts for Resource-Poor Farmers in Zimbabwe', in American Society of Agronomy, Crop Science Society of America and Soil Science Society of America, *Impacts of El Niño and Climate Variability on Agriculture.* ASA Special Publication No. 63, Madison, WI: American Society of Agronomy

Piha, M.I. (1993) 'Optimizing Fertilizer Use and Practical Rainfall Capture in a Semi-Arid Environment with Variable Rainfall', *Experimental Agriculture,* 29:405-415

Roe, D., Nelson, F. and Sandbrook, C. (2009) *Community Management of Natural Resources in Africa: Impacts, Experiences and Future Directions.* Natural Resource Issues No. 18, London, UK: International Institute for Environment and Development

Rogers DJ. 1996. Changes in disease vector distributions. In: Hulme M. (ed.) Climate change and southern Africa: an exploration of some potential impacts and implications in the SADC region. Norwich Climate Research Unit, University of East Anglia. 49–55.

Roncoli, C., Orlove, B.S., Kabungo, M.R. and Waiswa, M.M. (2011) 'Cultural Styles of Participation in Farmers' Discussions of Seasonal Climate Forecasting in Uganda', *Agriculture and Human Values*, 28:123-138

Rosenzweig, C., Casassa, G., Karoly, D.J., Imeson, A., Liu, C., Menzel, A., ... and Tryjanowski, P. (2007) 'Assessment of Observed Changes and Responses in Natural and Managed Systems', in *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the*

Intergovernmental Panel on Climate Change, Cambridge, UK: Cambridge University Press, pp.79-131

Rufino, M.C., Dury, J., Tittonell, P., van Wijk, M.T., Herrero, M., Zingore, S., ... and Giller, K.E. (2011) Competing Use of Organic Resources, Village-Level Interactions Between Farm Types and Climate Variability in a Communal Area of NE Zimbabwe', *Agricultural Systems,* 104:175-190

Rufino, M.C., Rowe, E.C., Delve, R.J. and Giller, K.E. (2006) 'Nitrogen Cycling Efficiencies Through Resource-Poor African Crop-Livestock Systems', *Agriculture, Ecosystems and Environment*, 112:261-282

Rukuni, M., Tawonezvi, P., Eicher C., Munyuki-Hungwe, M. and Matondi, P. (2006) *Zimbabwe's Agricultural Revolution Revisited,* Harare, Zimbabwe: University of Zimbabwe Publications

Rurinda, J., Mapfumo, P., van Wijk, M.T., Mtambanengwe, F., Rufino, M.C., Chikowo, R. and Giller, K.E. (2013). Managing soil fertility to adapt to rainfall variability in smallholder cropping systems in Zimbabwe. *Field Crops Research* 154:211–225.

Rurinda, J., Mapfumo, P., van Wijk, M.T., Mtambanengwe, F., Rufino, M., Chikowo, R. and Giller, K.E. (2012) *Integrating Soil Nutrient Management and Timing of Planting for Increased Maize Productivity Under Variable Rainfall in Eastern Zimbabwe,* paper presented at the Zimbabwe National Climate Change Symposium, 6-8 June, Harare, Zimbabwe

Rusinamhodzi, L., Corbeels, M., Zingore, S., Nyamangara, J. and Giller, K.E. (2013) 'Pushing the Envelope? Maize Production Intensification and the Role of Cattle Manure in Recovery of Degraded Soils in Smallholder Farming Areas of Zimbabwe', *Field Crops Research,* 147:40-53

SADC (2012) *Regional Agricultural Policy (RAP): Priority Policy Issues and Interventions,* Gaborone, Botswana: Directorate of Food, Agriculture and Natural Resources, Southern African Development Community

SADC (2003) *Towards Identifying Impacts of HIV/AIDS on Food Insecurity in Southern Africa and Implications for a Response: Findings from Malawi, Zambia and Zimbabwe,* Harare, Zimbabwe: Vulnerability Assessment Committee, Directorate of Food, Agriculture and Natural Resources, Southern African Development Community

Saka, J.D.K., Siable, P., Hachigonta, S., Sibanda, L.M. and Thomas, T.S. (2012) 'Malawi', in *Southern African Agriculture and Climate Change: A Comprehensive Analysis.* IFPRI Monograph, Washington, DC: International Food Policy Research Institute

Sanchez, P.A., Shephard, K.D., Soule, M.J., Place, F.M., Buresh, R.J., Izac, A.N., ... and Woomer, P.L. (1997) 'Soil Fertility Replenishment in Africa: An Investment in Natural Resource Capital', in Buresh, J.R., Sanchez, P.A. and Calhoun, F. (eds), *Replenishing Soil Fertility in Africa.* SSSA Special Publication 51, Madison, WI: Soil Science Society of America, pp.1-46

Sarch, M.T. and Allison, E.H. (2000) *Fluctuating Fisheries in Africa's Inland Waters: Well Adapted Livelihoods, Maladapted Management,* paper presented at the 10th International Conference of the Institute of Fisheries Economics and Trade, 9-14 July, Corvallis, Oregon / www.osu.orst.edu/dept/IIFET/2000/papers/sarch.pdf

Seo, S.N. and Mendelsohn, R. (2008) 'Measuring Impacts and Adaptations to Climate Change: A Structural Ricardian Model of African Livestock Management', *Agricultural Economics,* 38:151-165

Shackleton, C.M. and Shackleton, S.E. (2004) 'The Importance of Non-Timber Forest Products in Rural Livelihood Security and as Safety Nets: A Review of Evidence from South Africa', South African Journal of Science, 100:658-664

Shackleton, C.M., Shackleton, S.E. and Cousins, B. (2001) 'The Role of Land-Based Strategies in Rural Livelihoods: The Contribution of Arable Production, Animal Husbandry and Natural Resource Harvesting in Communal Areas in South Africa', *Development Southern Africa,* 18:581-604

Smit, B. and Pilifosova, O. (2003) 'From Adaptation to Adaptive Capacity and Vulnerability Reduction', in Smith, J.B., Klein, R.J.T. and Huq, S. (eds), Climate Change, Adaptive Capacity and Development, London, UK: Imperial College Press

Smit, B. and Wandel, J. (2006) 'Adaptation, Adaptive Capacity and Vulnerability', *Global Environmental Change,* 16:282-292

Smith, W. (1999) *Safety Nets in Malawi: How Much? For How Many?* Lilongwe, Malawi: The World Bank in Malawi

Stoorvogel, J.J. and Smaling, E.M.A. (1998) 'Research on Soil Fertility Decline in Tropical Environments: Integration of Spatial Scales', *Nutrient Cycling in Agroecosystems,* 50:151-158

Stringer, L.C., Dyer, J.C., Reed, M.S., Dougill, A.J., Twyman, C. and Mkwambasi, D. (2009) 'Adaptations to Climate Change, Drought and Desertification: Local Insights to Enhance Policy in Southern Africa', *Environmental Science and Policy,* 12(7):748-765

Synnevag, G. and Lambrou, J. (2012) *Climate-Smart Agriculture: Possible Roles of Agricultural Universities in a Strengthened Norwegian Climate Change Engagement in Africa.* Noragric Report No. 64, Ås, Norway: Department of International Environment and Development Studies, Norwegian University of Life Sciences

Tadross, M.A., Hewitson, B.C. and Usman, M.T. (2005) 'The Inter-Annual Variability of the Onset of the Maize Growing Season over South Africa and Zimbabwe', *Journal of Climate,* 18: 3356-3372

Tadross, M.A., Suarez, P., Lotsch, L., Hachigonta, S., Mdoka, M., Unganai, L., ... and Muchinda, M. (2009) 'Growing-Season Rainfall and Scenarios of Future Change in Southeast Africa: Implications for Cultivating Maize', *Climate Research,* 40:147-161

Tanyanyiwa, V.I. and Chikwanha, M. (2011) 'The Role of Indegenous Knowledge Systems in the Management of Forest Resources in Mugabe Area, Masvingo, Zimbabwe', *Journal of Sustainable Development in Africa,* 13:132-149.

Theu, J., Chavula, D. and Elias, C. (1996) 'Malawi: How Climate Change Adaptation Options Fit Within UNFCC National Communication and National Development Plans', in Smith, J., Bhatti, N., Menzhulin, G., Benioff, R., Budyko, M.I., Campos, M., ... and Rijsberman, F. (eds), *Adapting to Climate Change: An International Perspective,* New York, NY: Springer-Verlag

Thierfelder, C. and Wall, P.C. (2010) 'Investigating Conservation Agriculture (CA) Systems in Zambia and Zimbabwe to Mitigate Future Effects of Climate Change', *Journal of Crop Improvement,* 24:113-121

Thomas, D.S.G, Twyman, C., Osbahr, H. and Hewitson, B. (2011) 'Adaptation to Climate Change and Variability: Farmer Responses to Intra-Seasonal Precipitation Trends in South Africa', In Williams, C.J.R. and Kniveton, D.R. (eds), *African Climate and Climate Change*, Berlin, Germany: Springer Science+Business Media, pp.155-178

Thornton, P.K., Herrero, M., Freeman, A., Mwai O., Rege, E., Jones, P. and McDermott, J. (2007) 'Vulnerability, Climate Change and Livestock: Research Opportunities and Challenges for Poverty Alleviation', SAT *e-Journal,* 4(1)

Thornton, P.K, Jones, P.G, Owiyo, T., Kruska, R.L., Herrero, M., Kristjanson, P., ... and Kulkar, U. (2006) *Mapping Climate Vulnerability and Poverty in Africa.* Report to the Department for International Development, Nairobi, Kenya: International Livestock Research Institute

Thornton, P.K., van de Steeg, J., Notenbaert, A. and Herrero, M. (2009) 'The Impacts of Climate Change on Livestock and Livestock Systems in Developing Countries: A Review of What We Know and What We Need to Know', *Agricultural Systems,* 101(3):113-127

Thornton, P.K., van de Steeg, J., Notenbaert, A. and Herrero, M. (2008) *The Livestock-Climate-Poverty Nexus: A Discussion Paper on ILRI Research in Relation to Climate Change*. Discussion Paper No. 11, Nairobi, Kenya: International Livestock Research Institute

Tittonell, P., Giller, K.E. (2012). When yield gaps are poverty traps: The paradigm of ecological intensification in African smallholder agriculture. *Field Crops Research* 143:76–90.

Tittonell, P., Scopel, E., Andrieu, N., Posthumus, H., Mapfumo, P., Corbeels, M., ... and Mkomwa, S. (2012) 'Agroecology-Based Aggradation-Conservation Agriculture (ABACO): Targeting Innovations to Combat Soil Degradation and Food Insecurity in Semi-Arid Africa', *Field Crops Research,* 132:168-174

Twomlow, S., Mugabe, F.T., Mwale, M., Delve, R., Nanja, D., Carberry, P. and Howden, M. (2008) 'Building Adaptive Capacity to Cope with Increasing Vulnerability due to Climatic Change in Africa: A New Approach', *Physics and Chemistry of the Earth,* 33:780-787

UNDP (2008). *National Adaptation Strategy to Climate Change Impacts: A Case Study of Malawi,* United Nations Development Programme, New York, USA.

Unganai, L.S. (2009) 'Adaptation to Climate Change among Agropastoral Systems: Case for Zimbabwe', *IOP Conference Series: Earth and Environmental Science,* 6:412045

Unganai, L.S. (2000) *Application of Long Range Rainfall Forecasts in Agricultural Management: A Review of Africa's Experiences,* paper presented at the International Forum on Climate Prediction, Agriculture and Development, 26-28 April, Palisades, NY: International Research Institute for Climate Prediction

Unganai, L.S. (1996) 'Historic and Future Climate Change in Zimbabwe', *Climate Research,* 6:137-145

Unganai, L.S. and Murwira, A. (2010) *Challenges and Opportunities for Climate Change Adaptation among Smallholder Farmers in Southeast Zimbabwe,* paper presented at the 2nd International Conference on Climate, Sustainability and Development in Semi-Arid Regions, August 16-20, Fortaleza, Brazil

Vincent, K. (2004) *Creating an Index of Social Vulnerability to Climate Change for Africa.* Tyndall Centre Working Paper No. 56, Norwich, UK: Tyndall Centre for Climate Change Research, University of East Anglia

Vincent, K., Joubert, A. and Cull, T. (2011) *Overcoming the Barriers: How to Ensure Future Food Production Under Climate Change in Southern Africa.* Kulima Integrated Development Solutions, Cape Town, South Africa: Climate Systems Analysis Group, University of Cape Town

Waddington, S.R. and Karingwindi, J. (2001) 'Productivity and Profitability of Maize + Groundnut Rotations Compared with Continuous Maize on Smallholder Farms in Zimbabwe', *Experimental Agriculture,* 37:83-98

Walker, B., Holling, C.S., Carpenter, S.R. and Kinzig, A. (2004) 'Resilience, Adaptability and Transformability in Socio-Ecological Systems', *Ecology and Society,* 9(2):5

Warren, D.M. (1991) *Using Indigenous Knowledge in Agricultural Development.* World Bank Discussion Paper No.127, Washington, DC: The World Bank

Woittiez, L. (2010) *Non-Timber Forest and Rangeland Products to Reduce Food Insecurity at Times of Extreme Climatic Events: A Case Study of Wedza Communal Areas,* *Zimbabwe*, MSc thesis, Wageningen, The Netherlands: Wageningen University

Woittiez, L.S. Rufino, M.C., Giller, K.E. and Mapfumo, P. (2013) 'The Use of Woodland Products to Cope with Climate Variability in Communal Areas in Zimbabwe,' *Ecology and Society*, 18(4):24

World Bank (2008) *World Development Report 2008: Agriculture for Development – Response from a Slow Trade–Sound Farming Perspective,* Washington, DC: The World Bank

World Bank (2005) *Turning the Tide. Saving Fish and Fishers: Building Sustainable and Equitable Fisheries Governance,* Washington, DC: The World Bank

WorldFish Center (2009) *Climate Change: Research to Meet the Challenges Facing Fisheries and Aquaculture.* Issues Brief No. 1915, Penang, Malaysia: WorldFish Center

WorldFish Center (2007) *The Threat to Fisheries and Aquaculture from Climate Change*. Policy Brief, Penang, Malaysia: WorldFish Center

Young, G., Zavala, H., Wandel, J., Smit, B., Salas, S., Jimenez, E., ... and Cepeda, J. (2010) 'Vulnerability and Adaptation in a Dryland Community of the Elqui Valley, Chile,' *Climate Change*, 98:245-276

Ziervogel, G. and Calder, R. (2003) 'Climate Variability and Rural Livelihoods: Assessing the Impact of Seasonal Climate Forecasts in Lesotho', *Area*: 35(4):403-417

Zinyengere, N., Mhizha, T., Mashonjowa, E., Chipindu, B., Geerts, S. and Raes, D. (2011) 'Using Seasonal Climate Forecasts to Improve Maize Production Decision Support in Zimbabwe', *Agricultural and Forest Meteorology*, 151:1792-1799

Websites

www.southafrica.info/business/economy/econoverview.htm

www.indexmundi.com/zimbabwe/gdp_composition_by_sector.html

www.climatechange.worldbank.org/climatechange/content/mainstreaming-adaptationclimate-change-agriculture-and-natural-resourcesmanagement-project

www.unfccc.int/files/meetings/seminar/application/pdf/sem_sup5_south_africa.pdf

www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter11.pdf

www.idrc.ca/EN/Programs/Agriculture_and_the_Environment/Climate_Change_and_Adaptation_in_Africa/Pages/default.aspx

www.undp-alm.org/projects/sccf-cwdcc-zimbabwe

www.za.boell.org/downloads/hbf_web_zim_21_2.pdf

www.ifad.org/operations/projects/regions/pf/pub/climate.pdf

www.ifpri.org/sites/default/files/pubs/pubs/dp/ifpridp00714.pdf

www.ifad.org/lrkm/pub/fisheries.pdf

www.fao.org/fi/oldsite/FCP/en/ZWE/body.htm

www.assets.wwfza.panda.org.wwf-web-1.bluegecko.net/downloads/wwf_a4_fish_facts_report_lr.pdf

www.researchintouse.com/nrk/RIUinfo/PF/FMSP03.htm

www.comesa.int

www.nepad-caadp.net

www.africa-union.org/root/au/auc/specialprograms/nepad/nepad.htm

www.afdb.org

www.climatechange.worldbank.org/climatechange/content/mainstreaming-adaptationclimate-change-agriculture-and-natural-resourcesmanagement-project

www.faostat.external.fao.org/default.jsp

www.fao.org/ag/aga/glipha/index.jsp

www.fao.org/ag/agl/aglw/aquastat/dbase/index.stm

www.developmentgoals.org/poverty.htm

Future Agricultures

This **Working Paper** was written by **Paul Mapfumo, Abdulai Jalloh** and **Sepo Hachigonta** for the **West and Central African Council for Agricultural Research and Development (CORAF/WECARD)** and **Future Agricultures Consortium.** The FAC Working Paper series publishes work in progress by FAC members. All papers are technical research papers which have been peer reviewed, and are available in open access format. The series editors are **Paul Cox** and **Beatrice Ouma**. Further information about this series of Working Papers at: **www. future-agricultures.org**

The Future Agricultures Consortium aims to encourage critical debate and policy dialogue on the future of agriculture in Africa. The Consortium is a partnership between research-based organisations across Africa and in the UK. Future Agricultures Consortium Secretariat at the University of Sussex, Brighton BN1 9RE UK **T** +44 (0) 1273 915670 **E** info@future-agricultures.org

Funded By

IDRC CRDI

UKaid from the British people

The views expressed do not necessarily reflect the UK Government's official policies.